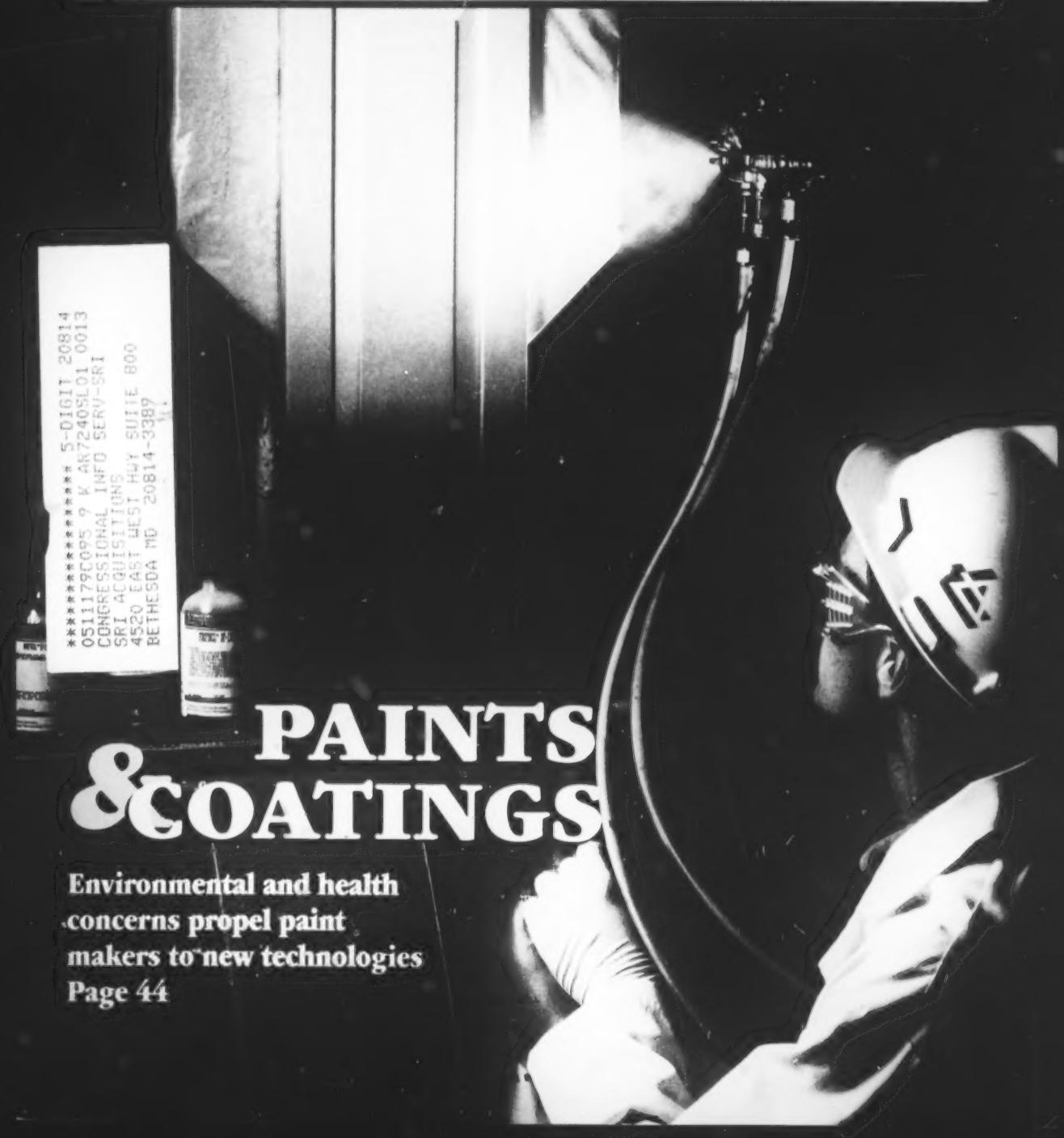
CHEMICAL & ENGINEERING NEWS

C&EN

OCTOBER 3, 1994

A1250-1

ORGANOMETALLIC CHEMISTS MAKE THEIR MARK ON MATERIALS SCIENCE PAGE 31



PAINTS & COATINGS

Environmental and health concerns propel paint makers to new technologies
Page 44

CHEMICAL & ENGINEERING NEWS

C&EN

OCTOBER 3, 1994

NEWS OF THE WEEK

■ New method maps the spatial arrangement of functional groups on a surface through attachment of specific chemical groups to the probe tip of an atomic force microscope. **Page 6**

■ Summit meeting between President Clinton and Russian President Yeltsin focuses largely on economic relations—promoting trade and investment—including in chemical-related areas. **Page 7**

■ Merck announces plan to fund establishment of a publicly available database of genetic information. **Page 7**

■ Stock prices of many small biotechnology companies plummet after demise of brokerage firm that invested heavily in this sector. **Page 8**

■ Breakthroughs in materials research that have led to commercially important materials and processes, or are likely to, are honored at a symposium in Washington, D.C. **Page 8**

■ Owens-Corning unveils a new glass fiber developed by fusion of two different forms of glass into a single filament. **Page 9**

COVER: Air Products & Chemicals scientist tests industrial coatings in temperature- and humidity-controlled spray chamber

Volume 72, Number 40
CENEAR 72 (40) 1-104
ISSN 0009-2347

BUSINESS

Demand for agricultural chemicals has rebounded in 1994 even as application volumes have decreased as a result of safer, more specific pesticides. **Page 13**

Most biotechnology companies are prepared to reemerge from difficult economic and political developments, according to a new industry report. **Page 17**

Business Insights: Recent survey shows strong public support for U.S. industry and manufacturing performance. **Page 18**

GOVERNMENT

Unfairness of Congressional earmarking of research funds is exposed at a hearing, but the practice is vigorously defended by academic institutions, some federal agencies find it useful. **Page 22**

National Science Foundation initiates efforts to establish performance indicators to be used in assessing results of federally funded research and education programs. **Page 26**

SCIENCE/TECHNOLOGY

Organometallic chemists find opportunities in the field of materials science as they focus on funding and selection of projects that may lead to commercial applications. **Page 31**

New thin-film semiconductor sensor that responds selectively to nitrogen dioxide has the potential for use in a variety of environmental applications. **Page 40**

ACS NEWS

ACS Committee on Professional Training reports on the number of 1993 bachelor's, master's, and Ph.D. chemistry graduates of schools with ACS-approved programs. **Page 72**

UCLA, Cornell, and UC Berkeley graduated the most B.S., M.S., and Ph.D. chemists, respectively, in 1993. **Page 79**

PAINTS & COATINGS

Against a backdrop of growth in sales and shipments, paints and coatings manufacturers are working to reformulate their products to meet clean air mandates while maintaining or exceeding current performance standards. **Page 44**

LETTERS 4

CONCENTRATES

Business 11

Government 21

Science/Technology 29

THE DEPARTMENTS

ACS Comment 71

Awards 80

New Products 85

Meetings 87

Newscripts 104

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: Rudy M. Baum, Ernest L. Carpenter, Janice R. Long, Rebecca L. Rawls, William J. Storck
Senior Correspondents: Lois R. Ember, James H. Krieger, Wilbert C. Lepkowski
News Editor: Richard J. Seltzer
Senior Editors: Northeast News Bureau: Marc S. Reisch, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Stuart A. Borman, Mairin B. Brennan, Doron Dagani, Bette Hileman, Pamela S. Zurer
News Bureaus: Northeast: (908) 906-8300 Ann M. Thayer (Head), Elisabeth Kirschner (Assistant Editor), George Peaff (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Houston: (713) 558-2912 Susan J. Ainsworth (Head). Washington: (202) 872-4495 David J. Hanson (Head), West Coast: (206) 517-5034 Deborah L. Illman (Associate Editor). London: (01) 44 81 870-6884 Patricia Layman (Senior Editor), (01) 44 256-811052 Michael Freemantle (Senior Editor)
ACS News Editor: Linda Romaine Ross
Editing and Production: Robin M. Giroux (Associate Editor), A. Maureen Rouhi (Associate Editor), Stephen K. Ritter (Assistant Editor), Arlene Goldberg-Gist (Head, Editing Services), Rita E. Johnson (Editorial Assistant)
Administrative Support: Patricia Oates (Administrative Assistant), La Trease Evans (Editorial Secretary)
Graphics and Production: Leroy Corcoran (Head), Barbara Fryer (Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing)
Composition Systems Administrator: Vincent L. Parker. **Assistant:** Robin L. Braverman
Business Manager: Arthur Poulos
Marketing Manager: David Schulbaum
Circulation Manager: Donna W. Carvana

ADVISORY BOARD: Marvin Cassman, Jerry Caulder, P. M. Chakrabarti, Rhetta Q. Davis, Peter B. Dervan, Gerald Epstein, Marye Anne Fox, Richard A. Lerner, Stephen J. Lippard, Peter J. Neff, James N. Pitts Jr., Douglas J. Raber, Bassam Z. Shakhashiri, Harold A. Sorgenti, Kathleen C. Taylor, Margaret A. Tolbert, Charles S. Tuesday, Theodore R. Williams

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Joseph A. Dixon *(Chairman); Board of Directors Chairman:* Paul H. L. Walter; *President:* Ned D. Heindel; Paul S. Anderson, Richard L. Deming, Paul W. Jennings, Barbara J. Peterson

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: ACS, Dept. L-0011, Columbus, Ohio 43268-0011. Correspondence and telephone calls for changes of address, claims for missing issues, subscription orders, status of records and accounts should be directed to: Manager, Member & Subscriber Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (800) 333-9511 or (614) 447-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1994: Printed editions: nonmembers U.S. 1 yr. $115, 2 yr. $217; outside U.S. 1 yr. $152, 2 yr. $281. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $18. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to C&EN, Member & Subscriber Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 103)
Office of Ombudsman: (800) ACS-5558, No. 5-4
© Copyright 1994, American Chemical Society
Canadian GST Reg. No. R127571347

LETTERS

Supply-and-demand equation

I would like to commend Attila Pavlath on his poignant commentary (C&EN, Sept. 12, page 46). As a recent Ph.D. graduate in inorganic chemistry of a well-respected school, I have given up after more than a year of fruitless job hunting, networking, hustling, even begging and pleading to be given a chance to work in a lab. I know I am not alone in what some have called the worst job market in 20 or more years.

During all of my undergraduate and most of my graduate school years, the American Chemical Society, the National Science Foundation, the Department of Labor, and other authoritative agencies claimed a "critical national shortage" of chemists and other technical people. In analogy to Pavlath's equation, this would be a case of 2 + 2 = 3. Attempts to make the equation equal involved the heavy and much-publicized recruitment of young and intelligent men and women into science. During this same time, much of industry saw the equation as being 2 + 2 = 5 and systematically downsized R&D. Academicians in universities were too busy writing grants and arguing over the mechanisms of addition and wondering how the equal sign works to notice any problem.

When combined, these three factors created a generation of young and highly trained scientists who either work like slaves in temporary postdoctoral positions or work in constant fear of whether the next paycheck will include "walking papers." The scientific community has created a very unhealthy situation for itself, which inevitably will ruin chemistry and science as a profession. Now is the time for ACS membership to take an active and leading role in resolving this problem. Failure to act now will only mean that the national meeting in the year 2020 will have to be held in a geriatric ward.

Carter White
San Diego

Influence of George Hammond

I was delighted to read that George Hammond has been chosen to receive the National Medal of Science. When I was a graduate student at Iowa State (1950–53) and he was a young faculty member, he had more of an influence on me than anyone other than my thesis adviser. His course on organic reaction mechanisms gave me, for the first time, an understanding of what organic chemistry is about. More to the point, he taught me to see chemistry as a unified subject, not a set of loosely related specialties. I still remember a chemistry department seminar he gave with the title, "We all wash dishes." It was, no doubt, the main reason that I managed to do research in physical, analytical, clinical, and biochemistry. I can't imagine a better career.

Marvin Margoshes
Tarrytown, N.Y.

Bricker, antibiotic analysis

Notice of the death of Clark Bricker (C&EN, Aug. 1, page 54) brought back the memory of his contribution to an analytical method for the quantitative spectrophotometric determination of solutions containing both of the antibiotics chlortetracycline (Aureomycin) and tetracycline (Achromycin).

I was in an analytical development group at Lederle Laboratories when tetracycline was synthesized by hydrogenating chlortetracycline, which was produced by a fermentation process. Individual solutions of chlortetracycline and tetracycline in concentrated sulfuric acid containing boric acid showed blue and red colors, respectively, to the eye (I may have the colors reversed—this took place more than 40 years ago). However, spectrophotometric curves showed absorbance maxima at wavelengths that were too close to allow two-component spectrophotometric determinations of solutions that contained both chlortetracycline and tetracycline.

Correction

• Sept. 19, page 12: Alberta & Orient Glycol (a joint venture of Union Carbide, Mitsui & Co. of Japan, and Far Eastern Textile of Taiwan) has ethylene glycol capacity at Red Deer, Alberta, Canada, of 660 million lb per year, not 1.3 billion lb. Union Carbide is the sole owner of another ethylene glycol unit with a 660 million-lb capacity at the same site.

Authorization to photocopy any article for internal or personal use beyond the fair use provisions of the Copyright Act is granted by ACS to libraries and other users registered with the Copyright Clearance Center (CCC), provided that the fee of $3.00 per article copy is paid directly to CCC, 222 Rosewood Dr., Danvers, Mass. 01923, USA. Copying for other than internal or personal use without express permission of ACS is prohibited. Address requests for customized bulk reprints to ACS Copyright Administrator, 1155—16th St., N.W., Washington, D.C. 20036, or call (202) 872-4367. The CCC Code for C&EN is 0009-2347/94 $3.00.

Agricultural Chemical Producers Rebound From Floods Of 1993

■ ***Increased acreage, higher prices, and drier weather are spurring bumper sales of more and safer products with improved packaging***

Elisabeth M. Kirschner,
C&EN Northeast News Bureau

Agricultural chemicals make up a nearly mature market, growing at about 4% per year in the U.S. However, this year is one of the better years in recent memory.

In response to higher cotton prices and summer floods in 1993, U.S. acreage—and the agricultural community's pesticide needs—has increased for the 1994 season. This year's more benign weather conditions and new products also contributed to the often impressive rise in demand for agricultural chemicals. Zeneca Ag Products president Bob Woods says his company's North American sales were up 23 to 25% over 1993's depressed figures.

But the business of pesticide producers is shifting under grower, consumer, and government demands. Safer chemicals and application technologies, as well as biological products, are increasing sales figures even as they bring volumes down. Herbicides, which gained in importance with the advent of soil-saving no-till farming, have been at the forefront of pesticides' growth in demand.

In this highly global industry, the U.S. accounts for about 24% of worldwide pesticide consumption by volume, but 34% by sales. And the U.S. has a positive trade balance in this market. Industry estimates of 1993 exports totaled $2.08 billion, with imports reaching $1.36 billion.

Europe—normally accounting for about 25% of global demand—saw pesticide use drop in the past two years, says John McDougall, analyst at Wood Mackenzie Consultants, Edinburgh, Scotland. Under the European Union's Common Agricultural Policy reform, which reduced government supports for cereal production, acreage decreased nearly 15%, he says. Growth should increase in developing countries, McDougall predicts, as industrialization takes workers off the farmland and international trade accords kick in.

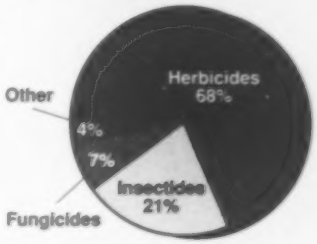
Worldwide, Ciba led 1993 sales with $2.77 billion, according to McDougall, followed by DuPont ($2.02 billion), Monsanto ($1.94 billion), Zeneca ($1.89 billion), Bayer ($1.70 billion), and Rhône-Poulenc ($1.68 billion). And, he says, the Hoechst-Schering crop protection joint-venture AgrEvo established last year would have accounted for nearly $2 billion in sales if the venture had been in operation for the entire year.

Compounding slow growth rates, the agricultural chemical industry also faces new costs from increased regulatory burdens. The Environmental Protection Agency has required producers to renew registrations on old pesticides to meet newer and stricter testing requirements. Phil Calderoni, business manager for pest control consulting at SRI International, Menlo Park, Calif., says the program encourages companies to drop the more toxic pesticides without necessitating an EPA ban.

But most drops in pesticide use are tied to economic considerations, says Zeneca's Woods. Zeneca has licensed products to other companies and dropped some minor uses—crops other than corn, soybeans, wheat, and cotton—because sales would be insufficient to offset reregistration costs. "We've spent $100 million to $150 million on reregistration," says Woods, with none of that going toward improving sales.

Meanwhile, developing a new pesticide can take sev-

Herbicides make up bulk of U.S. pesticide sales



Total 1993 pesticide sales = $6.8 billion

Source: American Crop Protection Association

DuPont photo

Increases in major crop acreage, such as corn, and better weather conditions have helped improve U.S. pesticide sales this year.

American Crop Protection Association photo

Application volumes have dropped as toxicity and specificity increase with new pesticides.

en to eight years, says Calderoni, with costs averaging $50 million. That, he says, as well as the competitiveness of the industry, has prompted consolidations such as AgrEvo to offset the costs of R&D, testing, and marketing.

In June 1993, EPA, the Department of Agriculture, and the Food & Drug Administration announced the Integrated Pest Management Program (IPM), which aims to reduce risks from agricultural and nonagricultural uses of pesticides. Although the initiative is expected to cut pesticide volumes, EPA's director of biological and economic analysis division, Allen L. Jennings, says that that is not the main goal. "We try to look at risk," he says, "which is a whole lot more than measuring pounds." Some options include smarter use of existing conventional pesticides, alternative technologies, and practices that reduce risk. This month, EPA plans to announce the first commodity-specific risk reduction plans developed by pesticide users. EPA's goal is to enroll 75% of agricultural acreage in IPM programs by 2000.

In the same vein, EPA has also implemented a reduced risk pesticide policy to streamline and speed registration for products that are safer than those now in use to get them to market sooner. Of 11 products proposed, six have been accepted for faster registration, and one—DowElanco's hexaflumuron termiticide—has already been accepted for registration, says John McCarthy, vice president of global scientific and regulatory affairs of the American Crop Protection Association (ACPA), Washington, D.C., formerly the National Agricultural Chemicals Association.

That shows the industry has been working toward safer technologies and IPM for years, says McCarthy. "The products that we see today were discovered eight to 10 years ago." Agricultural chemical companies are improving the molecules, using integrated approaches including biological control agents and genetic engineering to create insect- and disease-resistant plants, he says.

The name change to ACPA "captures the potential of today's biological and bioengineered products," says ACPA president Jay J. Vroom. For 1993, members reported $4.25 million in sales of *Bacillus thuringiensis* and other biologicals, compared with $6.8 billion in total sales of pesticides. A report from the Cleveland-based industry consultants, the Freedonia Group, predicts that biological pesticides will grow 19% per year through 1997.

The greatest pressure appears to be on atrazine herbicides, the largest volume pesticide, which EPA estimates reached 70 million to 75 million lb in 1993. Atrazine faces challenges because of its toxicity and potential for groundwater contamination. Other products, such as organophosphates and carbamates, face replacement because of insect resistance.

"There are terrific opportunities for new technologies to replace older ones," says DuPont agricultural products vice president William F. Kirk. DuPont has target-specific products as well as product systems under development, he says. In waste reduction, the company goal is to reduce packaging materials 50% by 2000 through technologies such as tablets and water-soluble film containers. Last month, DuPont opened a grain biotechnology R&D center in Urbandale, Iowa. Although traditional pesticides have increased acreage value by limiting pest damage, DuPont's grains strategy is to increase the amino acids or oil content of each plant to increase the sale price of each bushel.

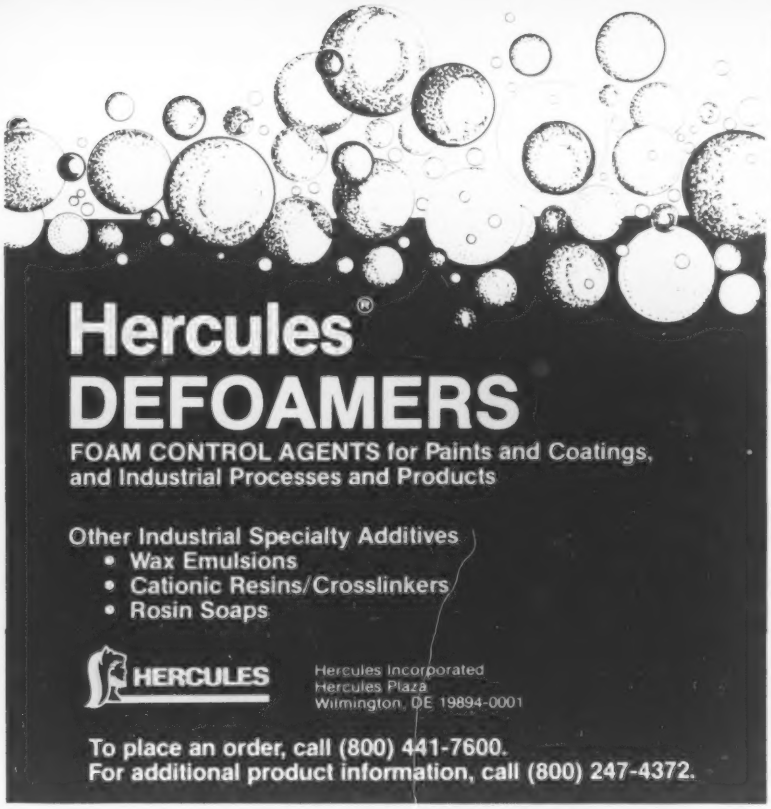
American Cyanamid is the fastest growing agricultural chemicals company according to McDougall. Ken Sekley, Cyanamid's marketing manager for retail distribution, attributes much of the company's double-digit growth in 1994 to the imidazolinone herbicides, which work at a level of 2 to 4 oz per acre compared to pounds per acre for older herbicides. Imidazolinone-tolerant corn has increased the herbicides' use this summer, adding to sales for soybean protection.

Cyanamid has also formed an alliance with Sandoz, copackaging imidazolinones with Sandoz herbicides for broad-spectrum weed control in soybean and corn crops. The company hopes to introduce another member of the imidazolinone family for broadleaf weed control in peanuts next year. With the expected change of corporate ownership, Sekley stresses the company's plan for continuity.

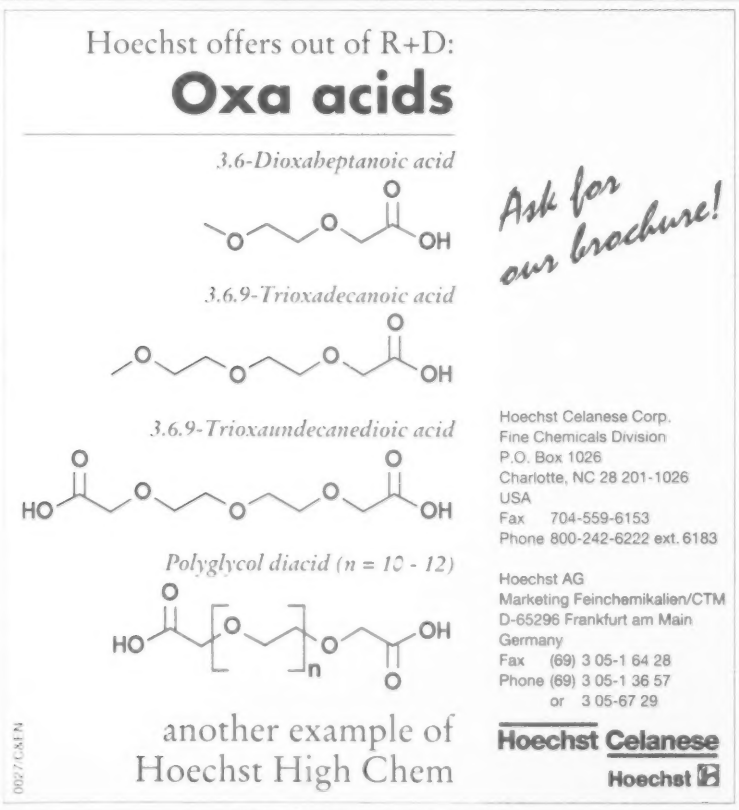
Rhône-Poulenc is working with agricultural biotechnology firm Calgene to develop a genetically engineered cotton that can tolerate its Buctril bromoxynil broadleaf herbicide. A company spokesman says that application after the crops emerge can reduce the number of applications and overall chemical use. The company is also banking on its fipronil insecticide, Regent, with a possible 1997 introduction for corn protection, to replace pyrethroids that have come up against resistant insects. Rhône-Poulenc is also beginning to license its gel technology for packaging pesticides. When a water-soluble pack is loaded into an applicator tank, the gel disperses in less than a minute, says the spokesman.

DowElanco is another product of consolidation in the industry, creating a critical mass for R&D. The company spends more than 10% of annual sales—which totaled $1.6 billion in 1993—on R&D. DowElanco's hexaflumuron termite-colony elimination system and a fermentation-derived insecticide are in the works. In the high-growth herbicide area, the company is expanding markets for its low-dosage flumetsulam product, Broadstrike. The herbicide, which has an application rate of teaspoons per acre, also has low toxicity, he says, because it interacts with an enzyme not found in people.

Zeneca's paraquat herbicides have continued to grow with the increasing no-till farming practices that minimize



CIRCLE 6 ON READER SERVICE CARD



CIRCLE 1 ON READER SERVICE CARD

soil erosion. And Zeneca is submitting its new alkyl ester fungicide—with its broad spectrum of uses and low environmental toxicity—for fast-track registration in 1995, says Woods.

Monsanto and Zeneca together received registration for acetochlor earlier this year. Acetochlor promises decreased herbicide volumes and lower carcinogenicity than existing corn herbicides. But because of toxicity concerns, the registration contained an unusual provision for revocation should residues leach into groundwater or herbicide volumes not decrease according to estimates. Sales have been "pretty good," says SRI's Calderoni.

Monsanto purchased the Ortho business from Chevron last year and is considered a likely partner or buyer of American Cyanamid's agricultural chemicals business should it be split off for sale. Monsanto has been developing a new low-use halosulfuron, with applications to be measured in fractions of an ounce per acre. Sulfonylureas, which include inhibitor functional groups on the molecule that can only be removed by certain insect enzymes, keep the toxic properties from being realized in other animals. Monsanto has also been developing crops resistant to its broad-spectrum glyphosate herbicide, Roundup, one of the "cash cows" of the industry. A Monsanto spokesman says a tolerant soybean hybrid is close to commercialization, and the company is also pursuing resistant corn and canola with seed companies.

Ciba is focusing on safer, more selective IPM-compatible products. They are more complicated molecules, says Don Allemann, manager of insect control research, with chemistries that vary widely. "The more you ask of a compound usually the more complicated it gets," he says. The newer entries are also much more active, requiring less volume. The company has concentrated considerably over the past five to six years on biologicals, he says, which may yield modest niche products. "We're not losing our focus on chemistry," he says. "Consumers want blemish-free fruits and vegetables, but they don't want any chemical residue." Using chemicals early in the season and biologicals later could solve this paradox, he says.

But no matter what the changes are in pest management, says McCarthy, "synthetic chemistry is still the backbone" of crop protection. □

Biotech industry readies for reform and renewal

After surviving recent difficult economic and political developments, the biotechnology industry is preparing for a turnaround. In the past 12 months, biotechnology companies have faced pressures emanating from the health care reform debate while watching capital markets shrink and potential major pharmaceutical partners undergo consolidation. But double-digit growth for most biotechnology industry measures and a strong outlook for new products are leading to expectations that biotechnology companies are reorganizing themselves in preparation for a reemergence.

These are some of the major conclusions in Ernst & Young's ninth annual report on the biotechnology industry, "Biotech '95: Reform, Restructure, Renewal." The New York City-based accounting and professional services firm developed the industry outlook after surveying nearly 400 biotechnology chief executive officers.

Overall, the biotechnology industry continued to show growth for the fourth consecutive year. Revenues rose 12%, to $11.2 billion, for the fiscal year between July 1993 and June 1994. Product sales accounted for 69% of all revenues—the remainder came from contract and collaborative R&D funding, licensing, royalties, and other income. Just 10 leading products had combined sales of $4.3 billion during the 1993 calendar year.

Despite the growth in sales and revenues, the industry still reported a net loss of just over $4 billion, up from a loss of $3.6 billion for the previous 12-month period. An increase in overall spending contributed to the loss. Much of the outlays went into R&D spending, which grew by 23% to reach an industry total of $7 billion.

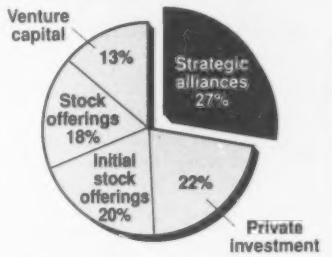
Public companies, which numbered 265 this year, contribute disproportionately to overall industry results. Revenues rose 18% for this sector, to $7.1 billion, and product sales were up 21%, to $5.2 billion. But the combined net loss of this sector grew to $2.1 billion from $1.5 billion the previous year. Among public companies, R&D spending rose 27% to a combined $3.8 billion.

The industry's year was not without its major challenges, particularly because of tightness in capital markets. The 1993–94 period was the first time in the industry's history that the number of startup companies declined. Startups dropped to 13 from 57 the year before and from an all-time high of 119 in 1987. The number of new companies formed was also the smallest since 1973, when there were only six.

The increased spending rate has led Ernst & Young to adjust its survival index—a measure of how many months of cash a company has left. At current spending levels, the median survival index for public companies has fallen to 25 months from 34 months last year. Less than a quarter of the companies are reported to have enough cash to survive for five or more years, and about 26%, up from 17% last year, have enough cash for less than one year of operation.

To survive, many companies are expected to refocus and reorganize their operations while continuing in the ever-constant hunt for cash. A total of $4.7 billion was raised by biotechnology companies between July 1993 and June 1994, a 17.5% increase over the previous year. Although funding was up, the number of deals made has dropped steadily in the past few months.

Most capital is raised by forming alliances



Total 1993–94[a] biotechnology industry financing = $4.74 billion

a Based on fiscal year from July 1 to June 30.
Source: Ernst & Young

Most biotech measures grow, including net loss

$ Billions	Public companies 1992–93[a]	Public companies 1993–94[a]	Public companies % change	Industry total 1992–93	Industry total 1993–94	Industry total % change
Product sales	$ 4.3	$ 5.2	21%	$ 7.0	$ 7.7	10%
Revenues	6.0	7.1	18	10.0	11.2	12
R&D spending	3.0	3.8	27	5.7	7.0	23
Net loss	–1.5	–2.1	40	–3.6	–4.1	14
Market capitalization	39.0	36.0	–8	45.0	41.0	–9
No. of companies	235	265	13	1,272	1,311	3
No. of employees	48,000	53,000	10	97,000	103,000	6

a Fiscal years from July 1 to June 30. **Source:** Ernst & Young

Financing through stock offerings became more difficult in the second quarter of 1994 and has continued to be so in the third quarter. The result has been a declining market value in the first nine months of 1994 for 82% of public biotechnology companies. For the period between July 1993 and June 1994, the market capitalization of the public companies dropped to $36 billion, from the previous year's $39 billion, although the number of companies rose by 30.

"While Congress continues to disagree over the contents of a health care bill, the dialogue alone may have served to accelerate market changes already in progress," says G. Steven Burrill, senior adviser to Ernst & Young. "Political reform's greatest impact has been to create higher levels of uncertainty that haunt the biotech industry in the financial markets."

But Burrill and his coauthor on the report, Kenneth B. Lee, national director for Ernst & Young's Life Sciences Industry Service, are optimistic that the changing health care market will accept innovative biotechnology therapies and products and understand their relative costs and benefits. A few new products approved last year—such as Genentech's Pulmozyme, Genzyme's Cerezyme, and Chiron's Betaseron—and others poised for approval in the coming year should add greatly to the performance of the industry. Major pharmaceutical producers are expected to continue to find biotechnology companies attractive partners for new product development, despite consolidation among the big companies.

Ann Thayer

Survey shows public support for U.S. manufacturing performance

Just what does the American public think of industry and especially manufacturing? In these days when television programs are replete with greedy corporate executives, polluting manufacturing companies, and shoddy, if not illegal, manufacturing practices, the question is a fair one. And it is a question that the National Association of Manufacturers (NAM) sought to answer in a survey of the public and Washington opinion leaders.

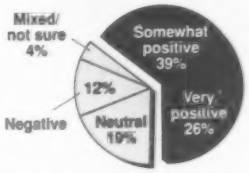
The answer, it turns out, is somewhat surprising, although certainly not unpleasing to the survey's sponsor. The U.S. public and its opinion leaders overwhelmingly approve of the job being done by U.S. manufacturing, according to the survey conducted by Peter D. Hart Research for the Manufacturing Institute, an education and research affiliate of NAM.

The responses show that 63% of the public surveyed approve of the way that manufacturing is doing its job, with only 27% disapproving. This ties with the survey ratings for approval of the performance of colleges and universities. In fact, all segments of industry score high in the approval ratings. Besides the strong support for manufacturing, 61% of the respondents approve of the performance of U.S. industry as a whole and of the performance of employers as well.

In fact, the only institutions included in the survey that do not get firm support for their job performance are Congress and political parties. Only 34% of the respondents approve of the job that Congress is doing, with 59% disapproving. And only 29% approve of the performance of political parties, with 62% disapproving.

The survey included interviews among a random sample of 751 adults nationwide, as well as 526 Washington opinion leaders—which included members of Congress and its senior staff, top executive branch officials, and members of the media—who returned a questionnaire they had been sent.

Manufacturing has a 65% positive rating



Source: National Association of Manufacturers

While 63% of the public respondents approve of manufacturing performance, among opinion leaders, the approval rating is much lower, with 51% approving of job performance and 13% disapproving.

In another area of the poll, about two thirds of the public express positive feelings about manufacturing, with 26% being very positive and 39% being somewhat positive. But, here too, differences do exist between the attitudes of the public and those of opinion leaders. For instance, the opinion leaders have higher positive attitudes toward manufacturing than the public has, with 78% running positive and 6% negative, compared with 65% positive for the public and 12% negative.

And there is one outstanding difference between the two groups. When asked what type of company will contribute most to U.S. growth in the next five years, 58% of the public cite manufacturing, whereas 38% view service industries as most important. Among the opinion leaders, the split was almost reversed, with just 33% favoring manufacturing and 56% seeing service industries as most important. Jerry Jasinowski, president of NAM, says, "Clearly the public is way ahead of Washington in understanding manufacturing's key role in our economic future."

Public approves of how industry does its job

	Approve	Disapprove
Manufacturers	63%	27%
Colleges	63	27
U.S. Industry	61	29
Employers	61	31
Congress	34	59
Political parties	29	62

Source: National Association of Manufacturers

Jasinowski further comments, "The public is also on target with regard to what the federal government should do to encourage the growth of U.S. manufacturing companies." He notes that the survey shows 78% of the public responses recommend tax breaks for businesses to invest in U.S. plants; 73% recommend reducing regulations that hinder growth; and 72% call for cost-impact studies before making policy changes.

In terms of product quality, 66% of the public believes that U.S. products have improved over the past five years, with 22% saying they have improved a lot and 44% saying they have become a little better.

The study points out that those especially likely to praise U.S. products are adults with incomes of more than $50,00(nen, and young adults (ages 18–29). In these three categories, about 75% say that U.S. products had improved, while 13% or less say the product quality had declined. Among the Washington opinion leaders, 92% believe quality has improved.

Jasinowski concludes: "The survey sounds a reassuring note that the public and Washington are beginning to appreciate the importance of manufacturing to America's economic strength. Our goal is to make sure this understanding leads to better cooperation among labor, management, and government so that U.S. manufacturing can continue to excel across the board."

The support among the public for manufacturing is so strong in the survey that perhaps the chemical industry, which has been much vilified by the public, should change its name to the molecular manufacturing industry.

William Storck

PAINTS & COATINGS

Government mandates, driven by environmental and health concerns, pressure industry to develop new technologies

Marc S. Reisch,
C&EN Northeast News Bureau

Paint and coating formulators had a good year in 1993, continuing the modest recovery begun in 1992. Sales rose 4% above those for 1992 to nearly $13 billion, and 1993 shipments rose more than 3% to nearly 1.1 billion gal, according to the Department of Commerce.

Preliminary figures for the first six months of 1994 indicate this year could be even stronger. But although the industry appears to be making solid advances in sales and shipments, it is racing behind the scenes to adapt to a rapidly changing regulatory scene.

The paint industry has been dealing for some time with government restrictions, such as those concerning volatile organic compounds (VOCs), precursors of lower atmospheric smog. Whenever possible, industrial paint consumers have shifted to newer technologies, such as heat-curable powder coatings and radiation-curable coatings. Both of these technologies can eliminate VOCs because they do not require the use of solvents.

Conventional liquid coatings include VOC-containing solvents that evaporate into the atmosphere as liquid coatings dry. However, radiation-curable coatings and powder coatings are only practical on specially adapted, original equipment manufacturers' product-coating lines. Conversion from liquid coatings to alternative systems can be quite expensive, so paint users are generally eager to continue using newly developed low- or no-VOC liquid coatings on their existing paint production lines.

However, the Clean Air Act of 1990 will effectively regulate liquid coatings widely used, for instance, to paint building interiors and exteriors, to maintain industrial plants and equipment, and to coat and protect furniture surfaces. The Clean Air Act will require state and local governments to develop plans, if they have not already done so, to lower regional atmospheric pollution in compliance with federal law. An element in those plans will enforce limits on VOCs emitted from liquid coatings as they dry.

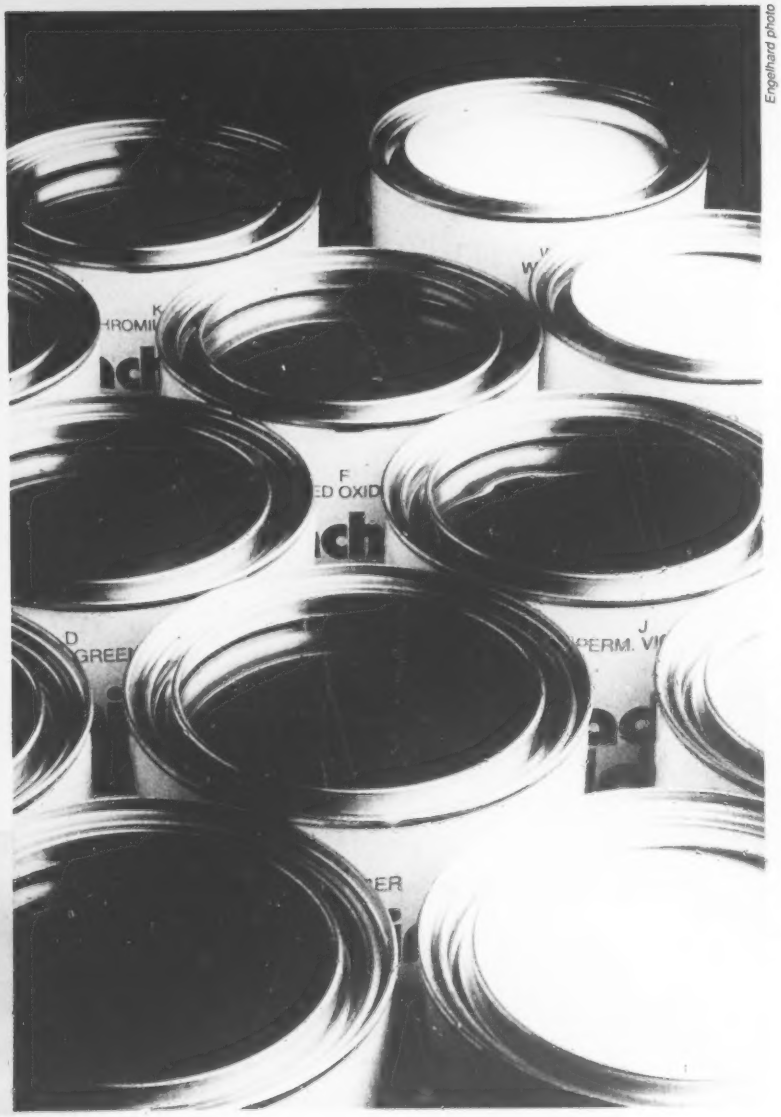
The Clean Air Act also complicates formulators' problems because the law will restrict the use of solvents considered hazardous air pollutants (HAPs). So manufacturers of liquid coatings must simultaneously meet VOC limitations and HAP restrictions.

The federal clean air mandates that affect the paint and coatings industry start to take effect in 1996. Manufacturers cannot dally if they want to sell liquid coatings in large metropolitan areas that do not meet air quality standards. As a practical matter, the law effectively forces most manufacturers to make all their liquid paints meet the strictest regulation.

The race to reformulate liquid coatings has opened up new opportunities for both paint formulators and material suppliers. Formulators who can sell paints that meet regulatory limits and still provide performance comparable with or even better than older products will have a marketing edge. Material suppliers have an opportunity to introduce new—and frequently higher priced—components that allow the production of low- or no-VOC coatings. Material suppliers thus have an opportunity to gain entry or market share even as they are introducing value-added, higher profit products into the market.

The effort to reformulate liquid coatings will also affect the market for relatively small high-performance materials. Silicone additives, used in minute quantities, give paint antifoam or easy wetting characteristics. Silicone resins—used at 20% or more by volume in a coating—add excellent weatherability and heat resistance to certain niche applications, such as for smoke stacks and barbecue grills. Other silicone formulations protect masonry from water damage.

How the manufacturers of specialty silicone materials cope with pending government regulations provides a study in the competition among the manufacturers of a particular class of material. Many silicone manufacturers, such as Dow Corning and Wacker, are making efforts to formulate their liq-



Engelhard photo

uid-coating offerings so that they are compatible with water-reducible and low-VOC systems. The silicone material manufacturers are also working to increase their market niche by reducing or eliminating the HAP solutions in which they have traditionally supplied silicones.

Paint shipments rose 3% in 1993

Paint shipments gained momentum again in 1993. According to the Department of Commerce, shipments rose modestly, a little more than 3%, following a 2% increase in 1992. Shipments in 1991 were down about 3% compared with 1990 as the industry felt the effect of a recession.

The growth of architectural coatings accounts for much of the increase in shipments. Shipments within that category rose nearly 5% to 604 million gal. The increase reflects not only a spurt in home building, but also an increase in consumer purchases. Since the economy has been recovering, more people have spent money to spruce up their homes.

Shipments of product coatings—which are used by original equipment manufacturers to protect automobiles, appliances, metal furniture, and other products—rose nearly 3% in 1993 to 321 million gal. Much of the increase in this category reflects strength in the manufacturing sector of the economy. Automobile manufacturers had a good year in 1993, and thus their use of paint accounted for a substantial portion of the increase in shipments for the category.

Only special-purpose coatings suffered a decline in shipments. Shipments of these coatings, which include, for example, bridge maintenance and highway traffic paints, were off more than 2% in 1993 to 169 million gal, following a nearly 4% decline in 1992. The decline suggests that local, state, and federal spending on infrastructure maintenance continues to be under budgetary constraints. It also suggests that a shift to higher solids-containing coatings, which cover more area per gallon, has played a role in reducing total shipments.

In dollar terms, the value of industry shipments in 1993 rose 4% over 1992 to just under $13 billion. Revised Commerce Department data show that industry shipments in 1992 rose more than 5%, compared with 1991, to about $12.4 billion.

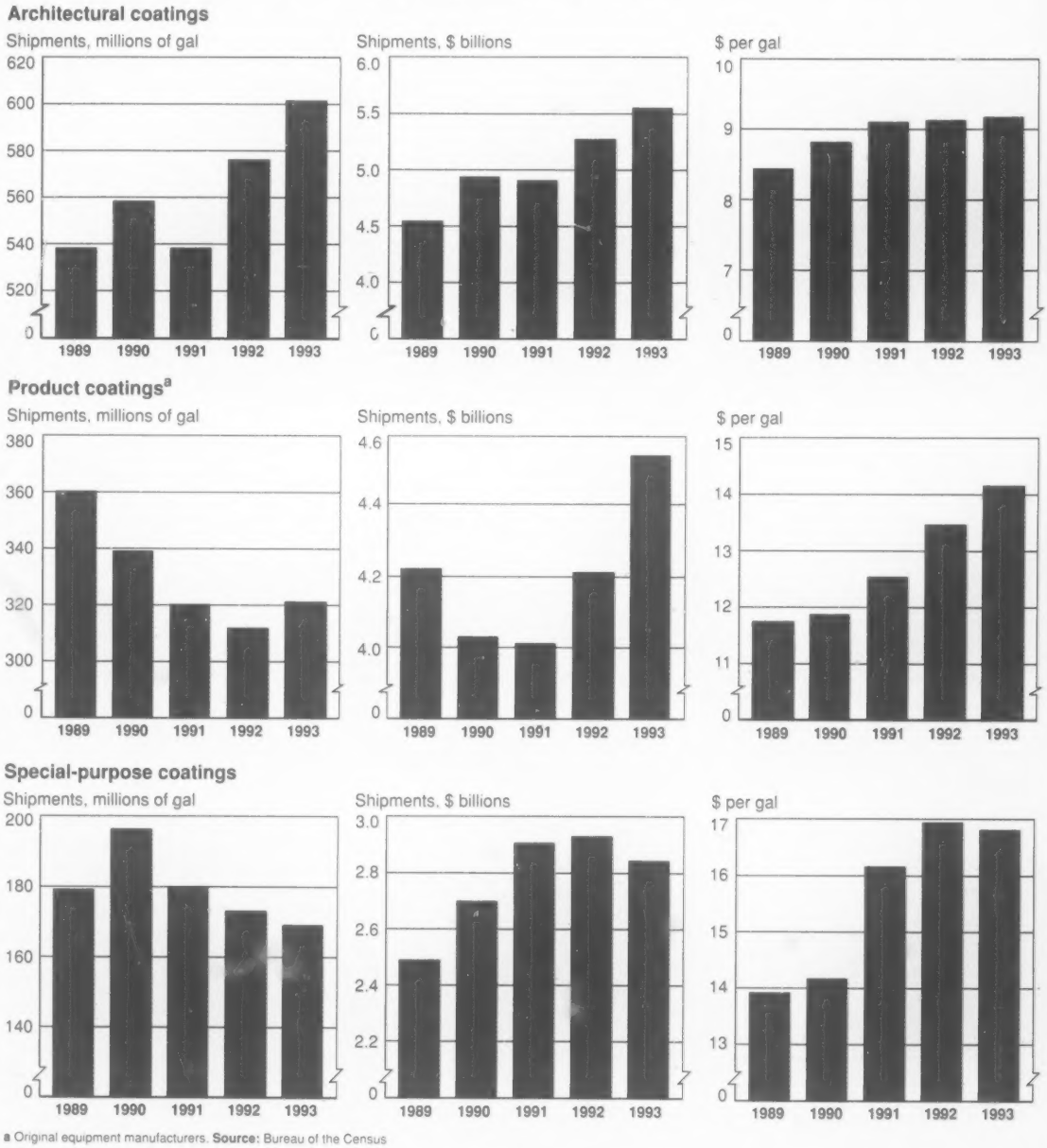
Within specific product categories, the value of architectural coatings shipments rose nearly 5% in 1993 to more than $5.5 billion, while product coatings shipments rose nearly 8% in value to more than $4.5 billion. The value of special-purpose coatings declined 3% to about $2.8 billion.

In 1993, architectural coatings accounted for 55% of all paint shipments, but only 43% of the value of total shipments. Product coatings accounted for 29% of shipments, but 35% of the value of total shipments; special-purpose coatings were 16% of all shipments, but 22% of the value of those shipments. These percentages do not change much from year to year.

A further look at paint industry data reveals that the average cost per gallon on the producer level averaged $11.82 in 1993, up less than 1% over the 1992 figure. Within individual market categories, average price per gallon for architectural paints was $9.19, up a mere penny from the year earlier. Product coatings prices rose nearly 5% to $14.14 per gal, and special-purpose coatings prices declined almost 1% to $16.80.

To illustrate the difference between producer costs, producer prices, and the cost per gallon that a retail consumer may pay, senior paint industry consultant Steven J. Nerlfi of consulting firm Kline & Co., Fairfield, N.J., notes that although architectural paint may average $9.19 on the producer level, the actual cost to produce the paint averages around $6.00 per gal. That means the paint formulator marks up the cost of paint by about 50%. The retail consumer pays, on average, $13.25

Product and architectural coatings shipments rose in 1993



a Original equipment manufacturers. **Source:** Bureau of the Census

for a gallon of architectural paint—representing a further 45% markup. The percentage markups and actual number of markups may vary by product category. For instance, paint formulators frequently sell paint directly to automobile manufacturers, who pay the producer price.

Per-gallon paint prices and material costs have been and are growing at less than the current inflation rate of between 3 and 4% for the past few years. According to the Department of Labor's producer price index, paint material costs declined almost 4% between 1990 and 1992. While average producer prices per gallon of paint rose less than 1%, paint material costs also increased less than 1% between 1992 and 1993. The period between January and August of this year shows a further increase of a little more than 1% for paint material costs. Prepared paint costs for the same period are also up about 1%.

Three main paint categories break down this way

Architectural coatings
- Exterior house paints
- Interior house paints
- Stains
- Undercoaters, primers & sealers

Product coatings[a]
- Appliances
- Automotive
- Electrical insulation
- Factory-finished wood
- Film, paper & foil
- Machinery & equipment
- Marine
- Metal containers
- Metal furniture & fixtures
- Nonautomotive transportation
- Pipe
- Sheet, strip & coil
- Toys & sporting goods
- Wood furniture & fixtures
- Miscellaneous consumer & industrial products

Special-purpose coatings
- Aerosols
- Arts & crafts
- Automotive & machinery refinishing
- Bridge maintenance
- High-performance maintenance
- Metallics
- Multicolored
- Roof
- Swimming pool
- Traffic marking

a Used by original equipment manufacturers. **Sources:** SRI International, Department of Commerce

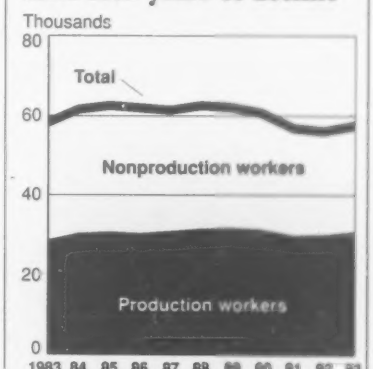
Over the next few months, prices of one of the most expensive paint ingredients, titanium dioxide (TiO_2), will probably rise. James R. Fisher, president of consulting firm International Business Management Associates, Princeton Junction, N.J., says TiO_2 prices rose 3% in April, but the increase was not fully effective until July. He expects to see another price increase—perhaps as high as 5%—by the end of 1994. Most new TiO_2 capacity is focused on serving fast-growing markets in the Pacific Rim, he notes, so prices in the U.S. and Europe for the pigment, an opacifying ingredient in most paint formulations, probably will remain high for the foreseeable future.

Over the past few years though, material price increases, including TiO_2 prices, and formulated paint price increases have been slim. Paint formulators have generally kept a cap on employment in recent years to control costs. Industry employment was 58,200 in 1993, almost 5% lower than the 61,200 level in 1990, when the industry sold just about as many gallons of paint. However, Labor Department data show that employment rose 2% in 1993 compared with 1992. To handle the increase in shipments between 1992 and 1993, the industry bolstered both production workers—to 30,500 in 1993 from 29,700 in 1992—and nonproduction workers—up to 27,700 in 1993 from 27,300 in 1992.

The slight increase in industry employment comes against a background in which the number of paints and coatings producers continues to decline. Industry sources estimate the number of coatings formulators in the U.S. at between 800 and 900. Ten years ago, around 1,300 formulators were producing in the U.S. Last year saw continuation of the trend in which large producers increase in size as they merge with or acquire others.

Perhaps the biggest business merger to affect the paint industry over the past 12 months was that of commodity and specialty chemical producers Akzo, based in the Netherlands, and Nobel Industries, based in Sweden, to form Akzo Nobel in February. In the U.S., the two companies have pooled their coatings formulations efforts in wood furniture finishes, coil coatings, and automotive refinish paints. In Europe and the Pacific Rim, the new company has strengths in those same markets; in addition, it is a major producer of decorative architectural coatings.

Paint employment is up after four years of decline



Source: Department of Labor

A number of smaller business mergers also took place during the past year. These include Sherwin Williams' acquisition of Old Quaker Paint, Grow Group's acquisition of Sinclair Paint, RPM's acquisition of Rust-Oleum; and Dexter's acquisition of both Potter Paint and Service Coatings. Many of these acquisitions have helped to fill in and strengthen the purchasing company's existing business. They also point out the vulnerability of smaller niche operations in a business climate where mostly the larger and better financed businesses can afford the effort to reformulate liquid coatings to lower VOCs and reduce or eliminate HAPs.

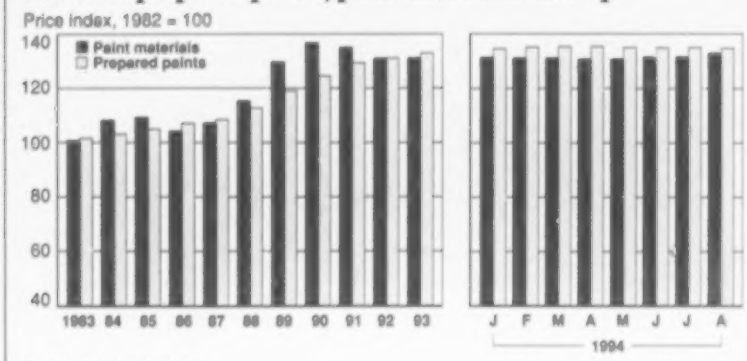
VOC reduction targets unclear

The VOC reduction targets that liquid paint manufacturers will have to meet are not yet finalized. What is clear is that paint formulators will have to lower VOC levels.

As part of its effort to help put clean air mandates into effect, the Environmental Protection Agency held a series of negotiations, which ended in August, with manufacturers of architectural and industrial maintenance coatings and interested parties. For more than two years, the group—which included manufacturers, environmental organizations, and state authority representatives—attempted to develop a plan to serve as a national framework to reduce VOCs emitted from paints. The group's goal was to come up with specific limits that would reduce VOCs emitted from paints in that category 25% by 1996, 30% by 2000, and as much as 40% by 2004—all based on 1990 emissions levels of approximately 990 million lb.

However, the group failed to reach an agreement. And the paint industry will now confront a scenario it had hoped to avoid. Bob Nelson, director of environmental affairs for the National Paint & Coatings Association in Washington, D.C., says that a number of states were counting on the national rule negotiations to use as a model in formulating their own local rules on VOCs. He says 33 states encompass localities where air

Prices of prepared paints, paint materials inch up



Source: Department of Labor

quality must be brought up to minimum acceptable standards, and thus paint manufacturers face a number of potentially differing VOC limits on liquid-coating categories.

The stakes were high in the architectural and industrial maintenance paint negotiations, Nelson points out, because the rules would have covered products that about 500 U.S. paint companies manufacture and that account for about 65% by volume of paint sold annually. If the VOC negotiations had been successful, they would have had the effect of postponing national rule making on HAP limitations for the architectural paint category until all parties could be reassembled to discuss limits. But with the failure of VOC negotiations, states can immediately begin their individual efforts to control both HAP and VOC paint rules, notes Nelson.

However, a second group, involving manufacturers of coatings for wood furniture, is now negotiating with EPA to set VOC and HAP limits simultaneously. That effort is closer to a final agreement, says Nelson, and the group is only working out the details of how limits will be monitored and how compliance will be ensured. Still other segments of the paint industry face the prospect of VOC limits in geographic regions they serve. An aerospace coatings advisory group has been discussing model VOC limits for airplane paint removal and coatings, says Nelson.

The fear among large- and medium-sized paint producers that serve a variety of geographic markets is that the Clean Air Act has opened a Pandora's box of regulations. And, as a result, they will have to deal with regulations that vary not only from state to state, but also from district to district within states where air quality restrictions could differ.

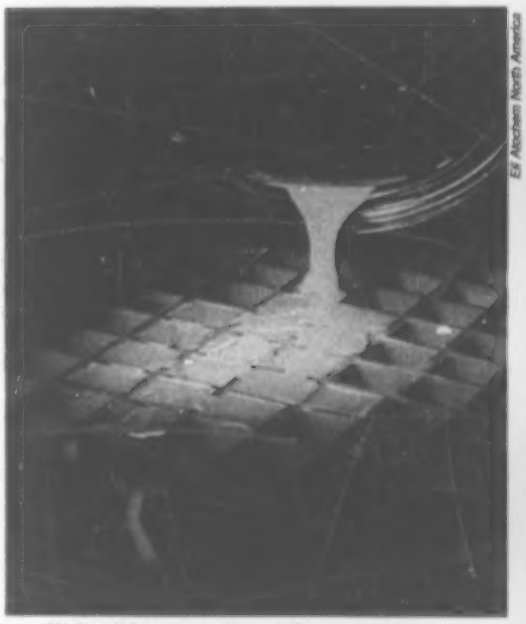
Fred Wissemann, a project manager with DuPont Auto Refinish Products, Wilmington, Del., notes he would like to see consistency among states on VOC limits affecting paint used to refinish cars in body shops. State authorities will be regulating the paints used by auto body shops as part of the effort to submit VOC reduction plans for approval to EPA. But no discussions are planned between EPA and auto refinish paint manufacturers to propose model national VOC rules. EPA is simply issuing technical guidelines to states on establishing auto refinish paint emission limits. Formulators will therefore have to make a number of individual efforts to reach state regulators if they are to secure regulatory consistency.

Akzo Nobel Coatings vice president of R&D in Troy, Mich., John L. Gardon, says the recent emphasis on pending regulation has created a climate for change in the industry. As a large supplier of coatings for industrial wood furniture finishing, Akzo Nobel sees its customers moving to high-performance aqueous coatings to replace higher solvent containing urea alkyds for kitchen cabinets. Waterborne systems to coat wood are also finally making inroads against the high-solvent containing nitrocellulose lacquer systems widely used for furniture. The automotive industry moved beyond nitrocellulose lacquer 40 years ago, notes Gardon, while the wood-coating industry stuck with older, familiar technology.

New resin developments in general have meant higher initial costs in some cases, notes Gardon. But he expects costs to moderate as new technology becomes more widespread. However, in some cases, higher costs for paints may be justified, especially when the effort to reformulate products for regulatory reasons also produces a coating system that performs better and lasts longer.

Realistically, the paint and coatings industry has been under pressure to reduce use of VOC-containing solvents for at least 15 years, notes paint industry consultant William Broxterman, president of ChemQuest Group, Cincinnati. Most large coatings formulators believe they can handle the transition to lower VOC coatings, he says. VOC and HAP concerns "are not overnight phenomena" after all, he adds. And despite the worry about regulation and its effect on business, the paint industry is relatively healthy now, he says, since

Continued on page 54



Elf Atochem North America

High-solids paint is dispensed into test trays.

Continued from page 50

both product sales and revenues are on the rise.

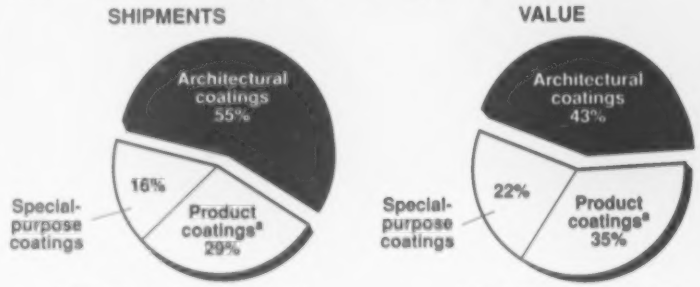
Regulations have provided opportunity for material suppliers, notes senior paint industry consultant Mike Growney, Kline & Co., Fairfield, N.J. Paint formulators will be under pressure to reduce the use of older aromatic and aliphatic solvents, among them toluene, xylene, and mineral spirits. Oxygenated solvents that are not considered HAPs should do well, he notes. In that category are solvents such as butyl acetate and ethyl acetate; propylene glycol-based products; some, but not all, ketone-based products (methyl ethyl ketone and methyl isobutyl ketone are considered HAPs); and dibasic esters.

The family of available solvents will grow, but the overall volume of solvents sold into the coatings market will decline in the long term, opines Growney. Considering the large number of specialty solvents the industry will have to choose from, prices for solvents generally will rise and will only come down if economies of scale come into play for certain preferred solvents. The search for solvent substitutes under regulatory pressure is causing a shift in both technology and thinking about the nature of coatings, he notes.

In the industrial maintenance arena, that has meant that coatings formulators and applicators are shifting to higher solids, low-solvent coatings as well as waterborne coatings. Formerly, high-solvent-content coatings were thought to perform best in industrial maintenance applications, notes consultant Jay Willner, president, WEH Corp., San Francisco. And solventborne coatings still perform best, he believes, in high-performance applications.

However, Willner estimates that manufacturers' sales of conventional lower performing, high-solvent coatings for commercial and institutional applications in schools, hospitals, and warehouses will decline from $235 million in 1993 to $185 million in 1998. Meanwhile, sales of waterborne coatings for similar applications will rise from $350 million in 1993 to $450 million in 1998. Sales of high-solids, low-solvent coatings that contain at least 60% solids will increase from $190 million in 1993 to $250 million in 1998. He believes, however, that conventional solventborne low-solids and high-solids coatings will continue to dominate industrial coatings for high-performance, severe exposure conditions, such as in petroleum plants, pulp and paper plants, and aircraft maintenance.

Architectural coatings lead in shipments and value



a Original equipment manufacturers. **Source:** Bureau of the Census

Solvent suppliers face VOC and HAP rules

Peter Doty, a Dow Chemical development associate, expects customers to choose solvents based on propylene glycol ether over ethylene glycol for both solventborne and waterborne formulations. Ethylene glycol solvents appear on the list of HAPs. But he points out that propylene glycols can seldom be one-for-one replacements for the ethylene glycol solvents. Reformulation with propylene glycols requires computer analysis to help find the best blend and further lab experimentation to confirm the best replacement.

On a pound-for-pound basis, however, propylene glycols contribute the same VOCs to a coating formulation as do ethylene glycols. But, says Doty, propylene glycols are "more efficient," and often a paint formulation requires less propylene glycol than ethylene glycol, thereby resulting in a lower VOC formulation. The cost to substitute propylene glycol for ethylene glycol depends on the ratio of substitution, but propylene glycol-containing formulations will generally be "slightly to moderately" more expensive.

Separately, Dow has introduced a new product, Proglyde DMM, a propylene-based di-ether, for use in both waterborne and solventborne urethanes. Its principal advantage is that it does not react with isocyanate-containing urethanes, and it provides good flow and leveling characteristics to the urethane coatings.

Dow Chemical technician evaluates panels for compliance with VOC regulations.

Arco Chemical, Newtown Square, Pa., is also a producer of propylene glycols. The company's product development manager, Zee Pongonis, says the company is also focusing its efforts on substituting propylene glycol-based products for ethylene glycol-based coalescents in waterborne coatings. In addition, the company has a line of reactive intermediates, such as 2-methyl-1,3-propanediol, to help lower the use of VOCs in urethane and polyester coatings. When the intermediate is "cooked into the backbone" of a monomer system, it produces a high-solids coating offering improved durability, weatherability, and gloss retention in industrial maintenance coatings, notes Pongonis.

International Specialty Products in Wayne, N.J., is hoping its *n*-methyl-2-pyrrolidone (NMP) will replace HAP solvents in both waterborne and high-solids solvent coating systems. According to global marketing director Van Rhonheimer, depending on the testing method, NMP "in general makes no VOC contribution." It is, however, a good coalescing agent in waterborne formulations, and it can replace more conventional solvents in solventborne coatings. NMP is not, however, a simple drop-in replacement for other solvents; it requires formulations study before being used in a coating.

Occidental Chemical, Dallas, has introduced a 35-year-old agricultural intermediate as a coating solvent because it is not a HAP, and it could qualify as a no-VOC contributor. Occidental Chemical has petitioned EPA to accept *p*-chlorobenzotrifluoride, trade named Oxsol 100, as a non-VOC, according to marketing manager Diane M. Tramontana. The company is currently testing the performance of Oxsol 100 in alkyd resins for architectural and industrial maintenance use versus currently used solvents. Because of Oxsol 100's price, Tramontana expects to see some blending of Oxsol 100 with more conventional VOC solvents as customers try to balance the final price of using the product against their ultimate VOC target.

Eastman Chemicals' Ron Litton, principal technical representative and supervisor of the company's coatings laboratory in Kingsport, Tenn., says Eastman's oxygenated solvents are aiding the ongoing effort to formulate away from HAP solvents. The company offers propylene glycol ethers, and its Texanol ester alcohol is a non-HAP coalescent that Litton says has been a standard in waterborne architectural coatings for more than 25 years. High molecular weight ethylene oxide glycol ether solvents supplied by Eastman to coatings formulators are still considered HAPs according to the Clean Air Act, but Litton says he hopes that EPA will change the designation.

A reactive diluent in a coating can also replace some solvent that would otherwise be required in a solventborne formulation, says Bill Reutz, technical oils department manager for Cargill, Minneapolis. The company's Dilulin diluent is a patented low-viscosity linseed oil copolymer with dicyclopentadiene. Dilulin is "basically a zero VOC" product, says Reutz, but since it increases the solids content of an oil-based coating, it goes on a surface as a thick coat that takes a longer time to cure than do conventional solventborne coatings.

Latest version of proposed national rules to limit VOCs in architectural and maintenance coatings

After two years of discussions, the industry group that EPA assembled to negotiate volatile organic compound (VOC) limits failed to agree on a final rule by the end of August. However, most group members could agree on the following VOC limits with help from EPA moderator Keystone Center, Keystone, Colo. Many within the paint industry hope the negotiated limits will provide a basic set of VOC limits for state authorities as they develop a variety of regulations to improve regional air quality to meet clean air mandates.

Category[a]	Proposed VOC limit (lb per gal) 1996	2000	2004
Flat coatings			
Exterior			
Solventborne	2.08	1.66	1.25
Waterborne	2.08	1.66	1.25
Interior	1.66	1.25	0.83
High-performance coatings			
Floor	3.33	2.92	2.5
Rust preventative	3.33	2.92	2.5
Concrete protective	3.33	2.92	2.5
Industrial maintenance coatings	2.92	2.92	2.5
Lacquers	5.66	5.42	5.0
Metallic pigmented coatings	4.16	3.75	3.33
Primers & undercoaters			
Waterborne	1.25	1.25	1.25
Solventborne	2.92	2.08	2.08
Quick-dry coatings			
Enamels	3.75	2.92	2.5
Primers, sealers & undercoaters	3.75	2.92	2.5
Roof coatings	2.08	1.66	1.66
Sealers—including specialty sealers	3.33	2.92	2.92
Shellacs			
Clear	5.42	5.0	5.0
Opaque	4.58	4.16	4.16
Stains			
Opaque			
Solventborne	2.08	2.08	1.66
Waterborne	1.66	1.66	1.25
Semitransparent	4.58	3.33	2.92
Low solids	1.0	1.0	1.0
Traffic-marking paints	1.25	1.25	0.83
Varnishes	3.75	2.92	2.5
Waterproofing sealers			
Clear	5.0	3.75	3.33
Opaque	3.33	3.33	3.33

a Proposed rule contains more than 50 paint categories. This table shows a representative sampling. **Source:** Keystone Center

Resins are one key to lower VOC

Kline & Co.'s Nerlfi believes that the development of new resin technology will make all the difference in the formulation of low-VOC coatings. Winning resin technologies, he says, include acrylic, polyester, epoxy, and aliphatic urethane formulations—all of which can be formulated as high-solids, low-VOC coatings or waterborne coatings. Losing technologies, he suggests, will be those that require a large amount of solvents (up to 70% by volume) for application, including nitrile, chlorinated rubber, neoprene, polyvinyl chloride, and alkyd formulations.

David Watson, maintenance coatings market manager for Rohm and Haas, Philadelphia, says waterborne acrylics can and do perform well in the tough, high-performance industrial maintenance arena.

Despite user preference for solvent-borne coatings, Rohm and Haas has made inroads in the industrial maintenance market. For instance, the company recently introduced Maincote PR71, a waterborne acrylic resin for priming metal. Watson says the resin can be used in a formulation with VOC levels well under 2 lb per gal, an improvement over high-VOC vinyl wash primers frequently used, and an emission level that could meet tentative EPA criteria for high-performance rust-preventive coatings.

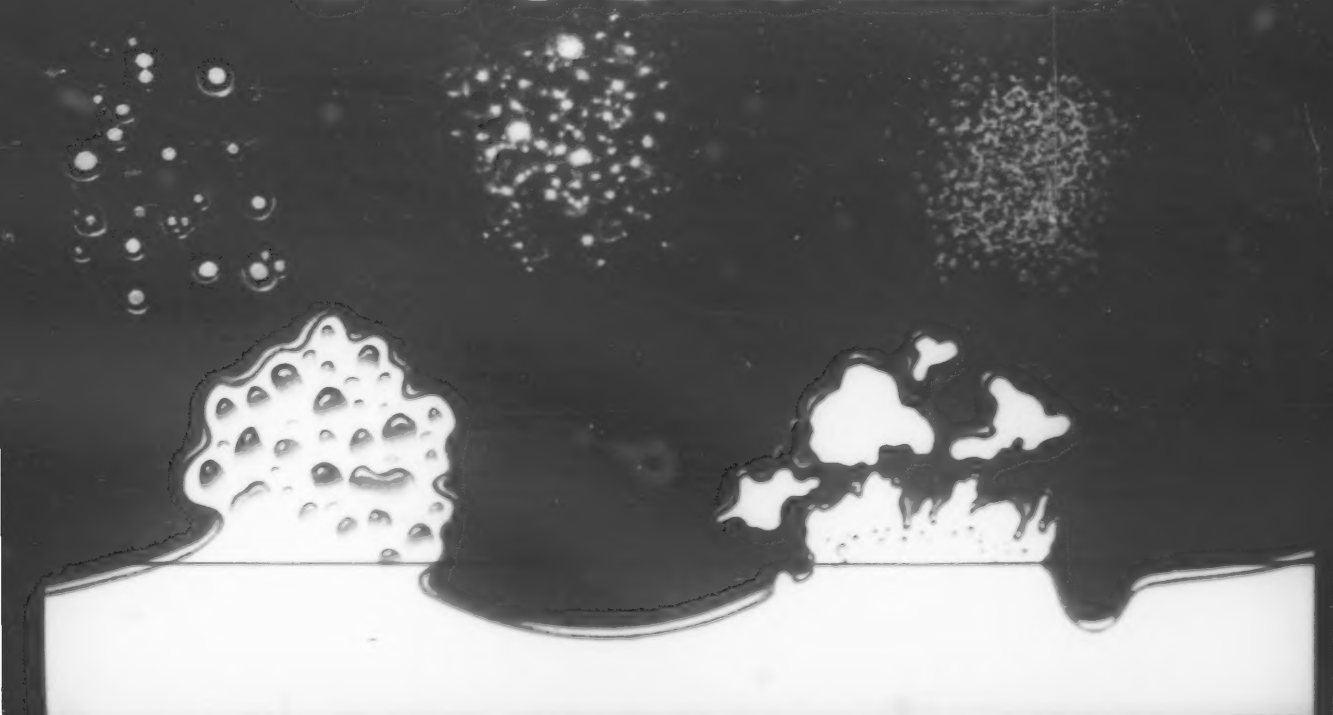
In addition to its well-known acrylic resins for waterborne coatings, Rohm and Haas offers acrylic polyols to formulate urethane coatings. The company now also has some waterborne acrylic polyols designed for use with wood coatings. And it is trying to develop waterborne acrylic polyols for the industrial maintenance business as well, says Watson. "We find waterborne coatings perform well in general, but it is hard to convince people [of that]," says Watson.

Another new technology for waterborne coatings is the development of a reactive coalescent that allows the formulation of coatings that contain essentially zero VOCs, says Watson. The coalescent is a monomer known as dicyclopentenyloxyethyl methacrylate, which Rohm and Haas conveniently refers to as QM57. The monomer self-cross-links in the finished coating. It is more expensive than traditional coalescents, notes Watson.

Pittsburgh's 9th Street Bridge was recently repainted with a three-coat polyurethane system containing coating resins made by Miles Inc.

Another manufacturer of urethane polyols, Miles Inc., based in Pittsburgh, has also put considerable effort into the development of waterborne systems as well as of high-solids, low-solvent systems. The company has helped the Navy develop a two-part waterborne polyurethane coating now being tested on the P-3 aircraft. The trick, says John L. Williams, Miles vice president of industrial finishes and resins systems, was to get the isocyanate cross-linker in the coating to disperse in water yet not react too quickly in water. The new gray coating has a

Problems.



VOC level of 1.76 lb per gal versus 3.5 lb per gal for the solventborne version.

Miles continues to develop both polyester and acrylic polyols for high-solids and waterborne system formulators, says Williams. In solvent systems, urethane formulators are making an effort to stay away from HAPs. However, Miles finds that when formulators move to low- or no-VOC systems, they also are able to remove HAP solvents from their systems. The efforts to reduce or eliminate HAPs and VOCs go hand in hand.

Air Products, Allentown, Pa., also produces urethane polyols. Larry E. Iceman, director of the company's industrial coatings initiative, says the company has recently introduced a line of patented hybrid acrylic urethane dispersions for water-reducible coatings. Sold under the Flexthane trade name, the new dispersions make it possible for formulators to produce polyurethanes with VOC levels of about 1.5 lb per gal. Iceman says the dispersions will be used in light- to medium-duty industrial maintenance and wood coatings. This fall, Air Products plans to introduce a two-part thermoset system for formulators based on Flexthane technology.

Air Products has also developed a modified aliphatic amine supplied in water and intended for use with other resin manufacturers' waterborne epoxy dispersions. The epoxy curing agent, Anquamine 401, cures rapidly and develops high gloss and good chemical resistance and is intended for use in systems to coat steel or concrete substrates, says Iceman.

Ultimately, says Iceman, Air Products' goal is to develop zero-VOC technology to end the "spiral" of lower and lower VOC-containing products. It is "expensive for everyone to constantly reformulate," he says.

Dow Chemical's Mark Sullivan, coatings market manager based in Midland, Mich., says Dow is offering customers a new epoxy powder that can be dispersed in water and formulated to contain no VOCs. Referred to by the rather unwieldy designation XUS 19,000.01, the epoxy powder can be a component in a two-part epoxy coating for industrial maintenance and institutional use such as in hospitals.

If customers prefer to work with solvent epoxies, Sullivan says Dow's new bisphenol F epoxy resins offer low viscosity and a high level of chemical resistance for civil engineering structures. The cost of the resin is twice that of bisphenol A epoxy, but the bisphenol F material allows the formulation of a high-solids resin. In prior years, performance drove development of new resin systems, Sullivan points out. Today, the effort to meet regulatory limits is of equal importance to performance-driven improvements, he says.

Eastman Chemical recently started up a new plant in Kingsport to produce commercial quantities of an intermediate in the production of polyester resins. Dennis J. Golob, market development manager in Eastman's coatings, inks, and resins business organization, says that 1,4-cyclohexanedicarboxylic acid is a monomer that poly-

Solutions.

NEWTON'S APPLE

3M

CIRCLE 18 ON READER SERVICE CARD

Paints use many hazardous air pollutants

Next month, a New York City-based environmental group, Inform, plans to publish a book, "Stirring Up Innovation," profiling five paint material suppliers and formulators that have successfully produced more environmentally benign products. The book's principal author, John S. Young, Hampshire Research Institute, Alexandria, Va., says the book will "highlight positive steps which can be taken in pollution prevention."

The book features paint material suppliers Ciba, Hüls America, and Miles Inc. for advances in marine antifoulants, colorants with no volatile organic compounds (VOCs), and polyurethane bridge coatings, respectively. It profiles Devoe & Raynolds and Glidden for low- or no-VOC paint developments.

In a discussion of environmental issues confronting paint formulators, "Stirring Up Innovation" inventories the following compounds used in paints that are identified as hazardous air pollutants in the Clean Air Act of 1990.

- Acetamide
- Acrylamide
- Acrylic acid
- Acrylonitrile
- Allyl chloride
- Aniline
- Benzene
- 1,3-Butadiene
- Caprolactam
- Catechol
- Cumene
- 1,2-Dichloroethane
- Dichloroethyl ether
- Diethanolamine
- Dimethylamino-azobenzene
- Dimethylformamide
- Dimethyl phthalate
- Epichlorohydrin
- Ethyl acrylate
- Ethylbenzene
- Ethylene dibromide
- Ethylenimine
- Formaldehyde
- Hexachlorobenzene
- *n*-Hexane
- Hydroquinone
- Isophorone
- Maleic anhydride
- Methanol
- Methyl ethyl ketone
- Methyl isobutyl ketone
- Methylene chloride
- Naphthalene
- Nitrobenzene
- 2-Nitropropane
- Pentachlorophenol
- Phenol
- Propylene oxide
- Styrene
- 1,1,2,2-Tetrachloro-ethane
- Toluene
- 2,4-Toluene diisocyanate
- 1,1,1-Trichloroethane
- Trichloroethylene
- 2,4,6-Trichlorophenol
- Vinyl acetate
- Vinyl chloride
- Xylenes
- *m*-Xylene
- *o*-Xylene
- *p*-Xylene

ester resin producers can incorporate into the backbone of a polyester resin.

The monomer modifies the polyester's performance, says Golob, making it tough, flexible, and chip resistant. It was first used in high-solids solventborne resin systems. But because the monomer gives polyester resins a new level of hydrolytic stability, it improves polyester resin performance in waterborne systems now under development.

Nacan, the Canadian affiliate of National Starch, Unilever's U.S. chemicals operation, has developed a line of acrylated ethylene vinyl acetate terpolymer emulsions that can be formulated into a flat or semigloss paint containing no solvents used as coalescents. The paint thus can be VOC free. According to Bill Currie, technology manager based in Nacan's Brampton, Ontario, headquarters near Toronto, the terpolymer, trade named Vinamul 3692, is manufactured in Woodruff, S.C., on the basis of technology Nacan brought to the U.S. from its Scandinavian and German affiliates.

Paint formulations based on Vinamul 3692 are now in use for architectural coatings, says Currie, and soon could find their way into industrial maintenance coatings. In addition, Nacan manufactures two all-acrylic emulsions for architectural coatings, Nacrylic 2592 for semigloss paints and Nacrylic 2792 for lower luster eggshell paints. Formulators also can use both emulsions to produce solvent-free coatings, says Currie. The acrylic emulsions are manufactured in Canada.

Even resin systems some may consider hopelessly tied to solvents have potential for development in an era of low-VOC paints. According to Vince S. Misiti, business development manager for ICI Industrial Surfactants in Wilmington, Del., the company offers a surfactant to emulsify alkyds in water, Atlas G-3969, and another surfactant, IL-2580, to emulsify epoxies in water. Misiti says these surfactants may be added at 5 to 10% by weight to the resins. The surfactants sell at a premium. Cost, says Misiti, is not so much the issue as are the environmental benefits that water-reducible resins provide. These surfactants will contribute some VOCs, but their contribution in a paint system will be much lower than that from a conventional solvent, he says.

Some manufacturers have attempted to produce lower molecular weight polymer versions of their high molecular weight solventborne polymers, says Misiti. The lower molecular weight materials dissolve more readily in water. But Misiti believes they would be better off with the higher molecular weight polymers to maintain the coating systems' strength and durability and instead utilize any number of ICI surfactants.

Surfactants may also replace some coalescing solvents in waterborne systems, says Misiti. ICI offers an ultralow-VOC specialty surfactant, Pycal 94, which can replace up to half of high-VOC coalescents such as ester alcohols and thus produce a latex paint with a VOC level as low as 0.5 lb per gal.

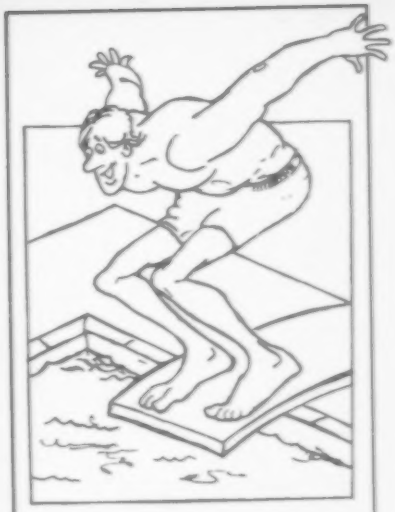
3M, Minneapolis, has a line of fluorochemical surfactants to lower the surface tension of waterborne coatings, especially when coalescing solvents have been removed from the formulation, comments chemical specialties marketing manager James W. Simmons. Although fluorochemical costs are relatively high compared with other surfactants, the fluorochemical surfactants are added at low enough levels to be competitive, he says.

Low molecular weight polymer additives can impart better performance characteristics to high solids and waterborne coatings. AlliedSignal's low molecular weight polyethylene resin modifiers, sold under the ACtol trade name, can improve the flexibility and impact resistance of reformulated coatings, says Arthur DeMonte, Western Hemisphere coatings marketing manager.

DeMonte says that AlliedSignal is also working with manufacturers on systems to improve highway striping paints. Where traditional highway paints are solventborne, new alternative thermoplastic tapes may be heated and applied to the road without emitting VOCs as the tapes cool and harden. AlliedSignal's new Polyace 573, a maleic anhydride-grafted polyethylene, can be used as an adhesion promoter for this technology, says DeMonte.

Elf Atochem North America, Philadelphia, has introduced new organic

Continued on page 64



Join the Pool and give a gift that gives back!

The ACS Pooled Income Fund lets you:

- Participate in ACS's future
- Earn income for life for you or someone else
- Receive an immediate charitable income tax deduction
- Avoid capital gains taxes on gifts of long-term securities

(open to members 60 and over)

For more details, please call, write, or mail this coupon to:

Development Office
American Chemical Society
1155 16th Street, NW
Washington, DC 20036
(202) 872-4094

NAME

ADDRESS

CITY

STATE ZIP

PHONE

Testing is vital to ensure performance of reformulated paints

Paint formulators are generally reluctant to reformulate a paint that has a history of good performance. "Why fool with success?" they may ask. But the existing and pending limits on volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) are forcing paint makers to reformulate many of their liquid-coating lines. Testing the new paints is more important than ever.

A. D. Little technician characterizes barrier properties of weathered paint panel.

According to John Martin, senior consultant in the polymer applications group for consulting firm Arthur D. Little, Cambridge, Mass., paint industry clients have generated a great deal of R&D activity on the issue of VOC reductions. "We can help the small- to medium-sized companies do the testing on reformulated coatings that the large companies with high R&D budgets can afford," he says.

About 5% of the 225 staff scientists at A. D. Little's Center for Product Development in Cambridge focus on corrosion and coatings, says Martin. The company undertakes research projects that range in duration from one month to several years.

Many paint companies use subjective methods to evaluate the performance of coatings, says Martin. But the use of lab analysis—objective methods—of coatings can yield good predictions on long-term performance of reformulated coatings. A new electrochemical technique that A. D. Little scientists use with painted panels entails outdoor exposure for 30 days and correlates to two years of exterior exposure. The technique allows paint formulators or material suppliers to tell in a month how new products may perform over the long term.

peroxides for use in acrylic resin production that allow the formulation of high-solids solventborne coatings. James D. Sargent, market manager for coatings, styrenated and specialty polymers, says *tert*-amyl peroxide initiators help resin makers produce an acrylic with a narrow molecular weight distribution that allows the production of a high-solids (up to 75%), low-viscosity resin for spray applications. The new peroxides are slightly more expensive than the *tert*-butyl peroxide or azonitrile initiators they are meant to replace, says Sargent.

To aid the development of low- or no-VOC paints, Hüls America, Piscataway, N.J., has a line of zero-VOC colorants. Thomas E. Maggio, executive vice president for colorants and coatings additives, says the Covon (no-VOC spelled backwards) line of colorants provides good drop-in replacements for VOC-containing glycol-based colorants more widely used now. Higher costs for some Covon system raw material ingredients have made the colorants more expensive than standard colorants, but Maggio expects prices to moderate as volumes increase.

Engelhard, based in Edison, N.J., also has a line of colorants that are solvent free or very low in VOCs for in-store custom coloring of consumer paints. The Gallery One Solvent Free line of colorants contains either no VOCs or such low levels of VOCs that VOC amounts are barely detectable, says Eliot Burrows, universal colorants business manager.

Colorant development group leader Jeff Norris says Engelhard is trying to anticipate government regulations by acting even if an ingredient only appears to be suspect. When concern was raised over the biodegradability of alkylphenol surfactants in colorants, Engelhard removed them from its line of colorants for manufacturers' use in their paint plants and introduced a new line of solvent-free colorants called Aurosperse II.

Heraeus DSET Laboratories in Phoenix can also assist clients in evaluating performance of reformulated coatings against traditional formulations that have years of testing behind them. William J. Putman, test services manager, says the company has two weather-testing sites: one in southern Florida, where paint panels are exposed under bright, hot, and humid conditions; and another in Arizona, where test panels may be exposed to high ultraviolet light at a hot, dry site.

The trick in evaluating new paints is in choosing the appropriate method to compare paints exposed under extreme accelerated test conditions with real-time exposures. Putman says that Heraeus, a privately held concern, works with customers to choose the most appropriate accelerated testing methods.

Air Quality Sciences (AQS), Atlanta, Ga., can verify for clients whether they have indeed succeeded in reformulating their coatings to reduce emissions. Many school districts and federal contracts put specific limits on the amount of VOCs that paints may emit during redecoration, says Marilyn S. Black, chairman of the testing company. AQS can provide independent verification that paints will perform as required, she says.

AQS can also perform a standard test to measure VOCs emitted from paint as it dries. The company uses a small stainless steel test chamber to measure VOCs emitted from paint by gas chromatography-mass spectrometry. Paints may also be evaluated in a room-sized environmental test chamber. Wallboard placed in the chamber and then painted allows AQS to provide its clients with a chemical analysis of chamber air, thereby giving a summary of chemicals to which a room's occupant may be exposed as paint dries. Black says that a basic test and chemical emissions report, which highlights chemical emissions that raise regulatory concerns, costs $1,600 per paint sample.

Heraeus DSET Labs

Paint exposure testing is conducted with a sun-tracking carousel.

Pending and future government regulations also affect the producers of specialty silicone materials—fluids and resins—that are added to paints and coatings. Fluids are added in minute amounts to impart antifoam and good wetting characteristics to paints. Resins are added to alkyd or polyester resins to formulate heat-resistant, gloss-retentive coatings with good weathering characteristics. And silicone products and silanes also may be used to waterproof concrete and masonry materials.

The size of the market for these silicone additives is difficult to gauge. Industry sources estimate that annual U.S. consumption of silicone fluids is about 170 million lb, of which paint and coating additives are a very small part. The fluids are typically added to paints at less than 1% by volume. U.S. silicone resin consumption is probably about 12 million lb per year, of which perhaps 4 million lb are used in paint resins. Sources say high costs limit silicones to specialty applications.

But performance is not the only criterion by which silicones are measured anymore. Silicone suppliers are also working to make products that contain low or no VOCs and no HAPs. Despite the small volumes of silicones used in paint, the U.S. paint market attracts a good number of competing suppliers—including Dow Corning, Wacker, General Electric, Miles, Hüls America, Rhône-Poulenc, and OSi Specialties.

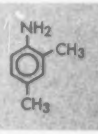
Perhaps the largest supplier to the paints and coatings industry is Dow Corning, Midland, Mich. According to Steve E. Tracy, senior product marketing specialist, silicone additives offer mar resistance, promote adhesion and water resistance, help with leveling and wetting paint off the brush, and prevent foaming of paint. The continuing move to waterborne coatings, he notes, has enlarged the market for silicone additives to provide some of the attributes of a coating lost in reformulating from solventborne technologies.

While he did not quote prices, Tracy

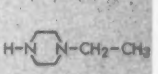
Organic Intermediates

for pharmaceuticals, agrochemicals, dyestuffs, flavors, fragrances, photochemicals, etc.

2,4-Xylidine
and other isomers

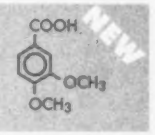


N-Ethylpiperazine

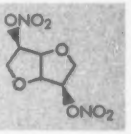


3,4-Dimethoxybenzoic acid
(Veratric acid)

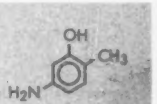
NEW



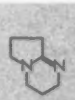
ISDN
Isosorbide dinitrate,
mixtures with lactose, etc.,
USP



5-Amino-o-cresol



1,5-Diazabicyclo-[4.3.0]non-5-ene
(DBN)



- Custom synthesis
- Nitration
- Catalytic hydrogenation

▲ 120.4.513

EMS

EMS-DOTTIKON AG
CH-5605 Dottikon, Switzerland
Phone 057 26 11 55
Telefax 057 24 21 20, Telex 827 923

US agents:
B.I. Chemicals, Inc./Henley Division
50, Chestnut Ridge Road, Montvale NJ 07645
Phone (201) 307-0422, Fax (201) 307-0424

CIRCLE 26 ON READER SERVICE CARD

does say that the additives offer a large benefit relative to their cost because they are often added at levels of 0.1% by volume to a paint formula. To measure the impact on paint formulation costs, a paint maker needs only to divide the additives' cost by 0.1% to see its impact.

Although paint additives are included in coatings in minuscule amounts, Dow Corning is formulating its additives to remove VOCs where possible, says coatings additives and resins industry manager Kim Evans. The same is true of Dow Corning's resins for paints. Many of the items in Dow Corning's product line are dissolved in HAP solvents, so the company is making an effort to upgrade its entire line.

One way in which Dow Corning intends to upgrade is through the production of dry-flake resins, such as the company's 10543 resin, which a paint formulator may emulsify in water. Another upgrade is the introduction of new emulsions for high-temperature applications including auto muffler and under-the-hood paints, such as resins 10468 and 10469, says Evans.

But while some formulators are making the leap to waterborne technology for certain products, others are taking a more cautious route with some high-performance coatings. In these cases, coatings manufacturers are first reformulating from low-solids to high-solids coatings before introducing a waterborne version, says Evans. To aid the development of high-solids, lower VOC, air-dried coatings for smokestacks, Dow Corning has introduced silicone resin 10418.

Technician at A. D. Little Coatings Laboratory prepares drawdowns for reformulation study of new coatings.

Evans says that Dow Corning also provides silicone materials for the formulation of masonry waterproofers. The company markets silanes used in clear, penetrating waterproofing coatings for parking decks as well as silicone latex emulsions used in pigmented waterproofing coatings for structural facades.

The production of low-VOC silicones is also a goal of Wacker Silicones, Adrian, Mich., the U.S. subsidiary of Wacker Chemie, Munich. In general, silicones are expensive, confesses Gudrun Windtuhr, construction and coatings industry market manager, but "you pay for the performance."

Wacker provides a variety of silicones that are applied to masonry surfaces to protect them from water damage. Siliconates and silicone emulsions are most often applied to masonry in water-based solutions. However, the company has introduced a microemulsion silicone concentrate that is low in viscosity and solvent free. The company says that aqueous solutions can be formed by simply pouring the microemulsion into water. However, the solution must be used within 24 hours after mixing with water if it is to effectively penetrate masonry. Wacker produces the microemulsion and other silicones—such as silanes, siloxanes, and siliconates—in Germany as well as in the U.S.

Roy Anderson, general manager of silanes and silicones for Hüls America, says the company is developing formulas for waterborne silicones because of existing and pending VOC regulations. Hüls has developed a series of organofunctional waterborne silanes, sold under the Hydrosil trade name, to promote adhesion in latex paints. The waterborne silanes required development of new technology because silanes are typically unstable in aqueous solutions, says Anderson. They may be incorporated into a latex formula at 2% or less by weight.

Hüls' line of masonry treatments has been expanded with a neat silane dispersed in water and sold under the Aquatrete trade name. Use of these masonry water repellents is growing, says Anderson, but is tied to construction activity. Typical uses include application to concrete decks in garages and bridges to repel water and help prevent corrosion of the steel rebar enforcement embedded in the concrete.

Miles has only recently entered the U.S. market with a line of silicone additives made by its German parent, Bayer. According to Miles' silicones product manager, Ken Kutzer, the company produces a line of polydimethyl siloxanes and phenyl methyl siloxanes to allow for better flow and defoaming of paints. At $10 to $12 per lb, the additives are not expensive—especially when they are added to a paint formulation at between 0.1 and 0.3% by weight, says Kutzer. Miles plans to introduce a line of four additives for water-based paints this fall, he says.

GE Silicones, Waterford, N.Y., is "looking into" the development of high-solids and water-reducible high-temperature resins, says Curtis Hughes, paints and coatings industry manager. When those products are developed, Hughes says, GE "plans to be a formidable player."

The use of silicone, like that of so many other paint ingredients, is now undergoing a reevaluation in light of regulatory pressures. Ultimately, successful material suppliers and formulators will produce products that comply with the most stringent regulations and offer the performance consumers are willing to pay for. □

Dow Corning technician tests viscosity of paint containing a silicone additive.

ACS Committee On Professional Training 1993 Annual Report

The number of bachelor's degree graduates in chemistry from colleges and universities whose undergraduate chemistry programs are approved by the American Chemical Society increased 4.3% in the 1992–93 academic year. The number of master's degrees from these departments increased by 4.1%, but the number of Ph.D. degrees granted decreased once again, showing a drop of nearly 3%.

The percentage of baccalaureate graduates certified to ACS was 41%. This number has remained fairly constant over the years. (Certified graduates are those who have completed a curriculum that meets the guidelines specified by ACS and who are eligible for full membership in ACS; noncertified graduates may become associate members of ACS upon graduation and full members after three years of professional experience or a higher degree in a chemical science.)

Total numbers of bachelor's degrees (certified and noncertified), master's degrees, and Ph.D. degrees awarded in 1992–93 by departments whose undergraduate chemistry programs are ACS approved are listed by institution in the large table at the end of this report and are summarized in the two smaller tables. These tables also include numbers of chemical engineering graduates from institutions whose programs are accredited by the American Institute of Chemical Engineers (AIChE) and the Accreditation Board for Engineering & Technology (ABET). [Note: These departments are not required to report their data to the Committee on Professional Training (CPT), so the number of departments included varies each year.] Also accompanying this report is a table with information on graduate student enrollments in chemistry departments whose undergraduate programs are approved by ACS.

The number of bachelor's degrees in chemical engineering from the 104 AIChE-ABET-accredited departments that reported in 1993 increased by 3.4%, even though fewer schools reported their data to ACS than in 1992. At the graduate level, the number of chemical engineering master's degrees decreased by 8.3%, and Ph.D. degrees dropped by 19.3%. However, for both categories, the number of schools reporting data to ACS was down from 1992.

The chemistry programs at ACS-approved schools normally are reevaluated at five-year intervals. There were 604 colleges and universities on the approved list at the end of 1993. During the year, the committee studied the reports of 197 chemistry programs at approved schools and 14 reports from schools applying for ACS approval. Each evaluation involved a review of extensive documentation submitted by the department chairman describing the current status of the program.

Three schools were added to the ACS-approved list by CPT; five were placed on probation; three were removed from probation; and two were removed from the approved list. Visiting

Summary of data from departments offering an ACS-approved program, 1989-93

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (totals)	Certified graduates[a]	Noncertified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1993	603	8,800	3,605	5,195	313	1,683	191	2,140
1992	601	8,435	3,604	4,831	314	1,617	192	2,202
1991	599	7,872	3,310	4,562	316	1,600	189	2,213
1990	599	7,650	3,213	4,437	317	1,605	187	2,131
1989	593	8,125	3,384	4,741	318	1,710	189	1,970
CHEMICAL ENGINEERING[b]								
1993	104	3,164	3,164	—	96	705	84	435
1992	112	3,060	3,060	—	107	769	92	539
1991	121	3,087	3,087	—	116	821	104	602
1990	126	3,170	3,170	—	122	956	106	583
1989	115	2,891	2,891	—	113	919	95	574

a Includes graduates certified in approved options. b Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year.

Summary of totals from 1993 reports from departments offering an ACS-approved program

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, Total	603[a]	5,228	3,572	8,800
Certified	—	2,225	1,380	3,605
Noncertified	—	3,003	2,192	5,195
Masters	313	1,003	680	1,683
Doctorates	191	1,523	617	2,140
CHEMICAL ENGINEERING				
Bachelors, Certified	104[b]	2,112	1,052	3,164
Masters	96	564	141	705
Doctorates	84	377	58	435

a One school did not report data. There were 604 ACS-approved programs in the 1992–93 reporting year. b Report forms were sent to 146 schools; only 104 departments responded.

associates of the committee made on-site visits to five schools.

Currently, students may receive certified degrees in chemistry with options in biochemistry, chemical physics, chemistry education, environmental chemistry, materials, or polymers. By the end of 1993, the committee had approved 62 programs with a biochemistry option; one with a chemical physics option; four in chemistry education; and nine with a polymers option. No applications for approval of materials options were reviewed in 1993, and the environmental chemistry option was not adopted until 1994.

In 1993, the committee continued discussion of the requirements for an ACS-approved option in environmental chemistry. Comments from the academic community were carefully considered by the committee members, and some modifications were made to the original proposal. Generally, the responses were enthusiastic, but a few respondents expressed concern that the options are too inflexible for undergraduates and that they pull students away from the traditional chemistry major. The committee welcomes further discussion of these concerns and invites those interested to comment by letter or directly with the members of CPT at an open meeting. The committee adopted the environmental chemistry option at its January 1994 meeting. The statement of requirements and application forms are available from the Office of Professional Training, ACS, 1155—16th St., N.W., Washington, D.C. 20036.

In October 1993, CPT published the 20th edition of the "ACS Directory of Graduate Research" (DGR). For the first time, programs in food science, forensic science, marine science, and toxicology were included in the directory. Complimentary copies were distributed to all departments listed in the 1993 directory and to all ACS-approved programs.

Also, in cooperation with the ACS Office of International Activities, the committee adopted a policy for distribution of complimentary copies of past editions of the DGR to chemists in appropriate foreign nations. The committee prepared a final report on the results of a survey of enrollment trends in freshman and sophomore chemistry courses and the numbers of chemistry majors at ACS-approved programs, and the chairman of CPT presented the results as part of a symposium sponsored by the ACS Division of Chemical Education. In institutions of all sizes, the survey data showed that more than half of the institutions responding experienced sizable increases in fall chemistry enrollments during the survey period (1988–92).

Other activities of the committee included discussion of how CPT might support the National Science Foundation's initiative in undergraduate chemistry curriculum development, revision of the five-year report form used to re-evaluate ACS-approved programs, development of plans to meet with chemical industry representatives to discuss the skills that industrial employers are seeking in chemistry graduates, and endorsement of the ACS task force initiative to encourage study abroad experience for chemistry students. In addition to the enrollment survey presentation, members of the committee also participated in other symposia held at ACS national meetings by giving presentations on the evolution of the CPT perspective on instruction in chemical information and on defining performance goals for the introductory chemistry course.

The committee would like to acknowledge and thank the following visiting associates of the committee who conducted on-site visits to schools on the approved list or applying for ACS approval during 1993: Charles A. Arrington Jr., Furman University, Greenville, S.C.; Ronald L. Christensen, Bowdoin College, Brunswick, Me.; James E. Finholt, Carleton College, Northfield, Minn.; Frank A. Guthrie, Rose-Hulman Institute of Technology, Terre Haute, Ind.; and Robert J. Hargrove, Mercer University, Macon, Ga. □

Committee members, 1993

Herbert D. Kaesz
committee chair
University of California, Los Angeles
Sally Chapman
Barnard College, New York City
Norman C. Craig
Oberlin College, Ohio
Dennis H. Evans
University of Delaware, Newark
Slayton A. Evans Jr.
University of North Carolina, Chapel Hill
Perry A. Frey
University of Wisconsin, Madison
Gordon A. Hamilton
Pennsylvania State University, University Park
Michael Jaffe
Hoechst Celanese Corp.
Dale W. Margerum
Purdue University, West Lafayette, Ind.
Jerry A. Mohrig
Carleton College, Northfield, Minn.
Jeanne E. Pemberton
University of Arizona, Tucson
Walter S. Trahanovsky
Iowa State University, Ames
C. David Gutsche, *consultant*
Texas Christian University, Fort Worth
Karen W. Morse, *consultant*
Western Washington University, Bellingham
Cathy A. Nelson, *committee secretary*
Stacie D. Marshall, *staff associate*
Dolphine S. Hite, *program assistant*
American Chemical Society

Graduate student enrollments in departments whose undergraduate chemistry programs are ACS approved

	Number of departments	First-year graduate students		All graduate students	
		Full time	Part time	Full time	Part time
M.S. DEPARTMENTS[a]					
Fall 1992	124	524	246	1,447	858
Fall 1991	124	511	262	1,424	909
Fall 1990	125	511	268	1,244	887
Fall 1989	130	429	238	1,013	834
Fall 1988	127	420	218	998	855
Ph.D. DEPARTMENTS					
Fall 1992	189	3,649	170	15,926	995
Fall 1991	192	3,736	267	16,864	1,170
Fall 1990	189	3,535	256	15,470	1,148
Fall 1989	187	3,464	159	15,222	1,207
Fall 1988	189	3,320	171	15,125	1,111

[a] Departments whose highest offering is the master's degree in chemistry

Chemistry and chemical engineering degrees awarded by schools offering an ACS-approved program, 1992-93

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Abilene Christian U	4	1	0	—			
Adelphi U	0	1	6	—			
Agnes Scott C	1	1	—	—			
Akron, U of	19	0	2	12	(a)		
Alabama, U of							
Birmingham	3	8	1	2			
Huntsville	3	4	2	—	(a)		
Tuscaloosa	3	8	2	11	18	1	1
Alaska, Fairbanks, U of	2	2	2	0			
Albion C	0	10	—	—			
Albright C	6	6	—	—			
Alfred U	1	1	—	—			
Allegheny C	0	15	—	—			
Alma C	7	4	—	—			
American U	3	0	9	10			
Amherst C	0	5	—	—			
Andrews U	2	0	—	—			
Appalachian State U	4	5	0	—			
Arizona State U	17	13	8	13	12	6	6
Arizona, U of	12	9	8	21	(a)		
Arkansas State U	3	5	4	—			
Arkansas Tech U	1	3	—	—			
Arkansas, U of							
Fayetteville	4	4	4	12	35	8	1
Little Rock	4	8	1	—			
Ashland U	0	2	—	—			
Auburn U	15	3	11	4	62	14	5
Augsburg C	9	0	—	—			
Augustana C							
Illinois	1	8	—	—			
South Dakota	3	4	—	—			
Austin C	0	7	—	—			
Austin Peay State U	2	6	—	—			
Baldwin-Wallace C	2	17	—	—			
Ball State U	15	7	8	—			
Barnard C	0	6	—	—			
Bates C	3	5	—	—			
Baylor U	5	11	1	3			
Beloit C	0	12	—	—			
Bemidji State U	12	14	—	—			
Birmingham-Southern C	0	3	—	—			
Bloomsburg U	5	4	—	—			
Boise State U	0	5	—	—			
Boston C	5	5	3	6			
Boston U	19	4	5	13			
Bowdoin C	0	25	—	—			
Bowling Green State U	12	11	8	0			
Bradley U	0	12	0	—			
Brandeis U	0	9	5	7			
Bridgewater State C	3	5	3	—			
Brigham Young U	11	22	1	8	27	4	1
Brown U	0	22	1	12	4	2	0
Bryn Mawr C	12	0	5	0			
Bucknell U	8	12	4	—	31	2	—
Butler U	5	13	3	—			
California Institute of Tech	14	5	4	30	6	17	6
California Polytech State U	16	45	—	—			
California State Polytech U	5	16	7	—	34	—	—
California State U							
Bakersfield	3	8	—	—			
Chico	0	13	—	—			
Dominguez Hills	5	0	—	—			
Fresno	15	11	5	—			
Fullerton	4	27	5	—			
Hayward	7	14	2	—			
Long Beach	5	45	4	—	(a)		
Los Angeles	9	10	9	—			
Northridge	8	18	4	—			
Sacramento	12	20	7	—			
San Bernardino	1	9	—	—			
Stanislaus	2	4	—	—			
California, U of							
Berkeley	23	39	8	54	84	13	19
Davis	41	16	3	20	(a)		
Irvine	12	52	13	23			
Los Angeles	13	139	12	41	30	9	4
Riverside	10	3	2	5			
San Diego	69	1	19	35	18	0	2
Santa Barbara	10	6	8	8	(a)		
Santa Cruz	3	14	1	7			
Calvin C	1	10	—	—			
Canisius C	3	3	—	—			
Capital U	0	2	—	—			
Carleton C	9	15	—	—			
Carnegie Mellon U	15	4	5	6	44	6	16
Carroll C	1	5	—	—			
Carthage C	1	1	—	—			
Case Western Reserve U	5	33	10	8	30	3	7
Catholic U of America	1	3	3	2			
Centenary C of Louisiana	0	2	—	—			
Central Connecticut State U	5	0	1	—			
Central Florida, U of	11	0	5	—			
Central Michigan U	4	13	8	—			
Central Oklahoma, U of	4	5	—	—			
Central State U	1	5	—	—			
Central U of Iowa	1	4	—	—			
Centre C	0	0	—	—			
Charleston, C of	10	24	—	—			
Chatham C	3	0	—	—			
Chestnut Hill C	0	3	—	—			
Chicago State U	0	9	—	—			
Chicago, U of	11	9	7	23			
Christian Brothers U[b]					(a)		
Cincinnati, U of	26	0	16	24	43	8	2
Citadel, The	0	2	—	—			
City U of New York							
Graduate Center				28			
Brooklyn C	1	26	6	—			
City C	0	17	30	—	(a)		
Herbert H. Lehman C	8	0	—	—			
Hunter C	0	11	—	—			
Queens C	0	20	2	—			
Clarion U	6	2	—	—			
Clark U	6	8	3	4			
Clarkson U	4	2	6	10	50	5	5
Clemson U	5	3	3	8	39	7	1
Cleveland State U	12	0	8	5	(a)		
Coe C	1	4	—	—			
Colby C	2	5	—	—			
Colgate U	8	7	—	—			
Colorado C	11	1	—	—			
Colorado School of Mines	3	0	4	6	51	2	4
Colorado State U	11	5	2	10	9	5	4
Colorado, U of							
Boulder	7	45	7	21	42	13	13
Colorado Springs	3	1	—	—			
Denver	6	6	0	—			
Columbia U	9	10	11	15	(a)		
Concordia C	3	4	—	—			
Connecticut C	0	4	—	—			
Connecticut, U of	10	7	11	8	23	3	0
Cooper Union [b]					(a)		

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Cornell C	0	9	—	—			
Cornell U	7	35	46	26	51	11	6
Creighton U	22	1	—	—			
Dartmouth C	0	29	2	3			
David Lipscomb U	1	14	—	—			
Davidson C	1	8	—	—			
Dayton, U of	2	4	1	—	32	3	—
Delaware State U	4	1	4	—			
Delaware Valley C of Science & Agriculture	11	0	—	—			
Delaware, U of	25	13	5	16	37	10	23
Delta State U	1	11	—	—			
Denison U	4	1	—	—			
Denver, U of	1	3	2	0			
DePaul U	2	8	12	—			
DePauw U	0	9	—	—			
Detroit Mercy, U of	4	3	17	6	13	10	1
Dickinson C	0	4	—	—			
District of Columbia, U of the	3	2	—	—			
Drake U	0	1	—	—			
Drew U	1	2	—	—			
Drexel U	6	0	6	4	(a)		
Duke U	8	25	3	14			
Duquesne U	3	5	4	1			
Earlham C	0	11	—	—			
East Carolina U	5	4	6	—			
East Stroudsburg U	6	6	0	—			
East Tennessee State U	7	13	4	—			
East Texas State U	0	5	1	—			
Eastern Illinois U	6	3	2	—			
Eastern Kentucky U	2	11	4	—			
Eastern Michigan U	7	22	11	—			
Eastern New Mexico U	3	6	2	—			
Eastern Washington U	0	13	2	—			
Eckerd C	0	2	—	—			
Elizabethtown C	1	6	—	—			
Elmhurst C	1	11	—	—			
Emory U	2	39	5	20			
Emporia State U	3	3	1	—			
Evansville, U of	4	5	—	—			
Fairfield U	5	1	—	—			
Fairleigh Dickinson U							
Madison	2	0	1	—			
Teaneck	1	1	1	—			
Fisk U	6	6	1	—			
Florida A&M U	0	1	0	—			
Florida A&M U/ Florida State U[b]					22	1	1
Florida Atlantic U	7	15	5	—			
Florida Institute of Tech	1	4	0	0	(a)		
Florida International U	4	15	2	—			
Florida State U	6	35	7	8			
Florida, U of	9	27	6	26	34	3	10
Fordham U	0	10	—	—			
Fort Lewis C	3	9	—	—			
Framingham State C	7	0	—	—			
Franklin & Marshall C	9	3	—	—			
Furman U	25	0	7	—			
Geneva C	2	8	—	—			
George Mason U	11	2	5	0			
George Washington U	1	11	0	2			
Georgetown U	14	0	11	10			
Georgia Institute of Tech	29	0	13	17	84	11	12
Georgia Southern U	1	2	—	—			
Georgia State U	0	8	4	3			
Georgia, U of	9	14	5	12			
Gettysburg C	8	3	—	—			
Gonzaga U	4	2	—	—			
Goucher C	3	4	—	—			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Grand Valley State U	2	10	—	—			
Grinnell C	4	12	—	—			
Gustavus Adolphus C	0	15	—	—			
Hamilton C	1	3	—	—			
Hamline U	8	1	—	—			
Hampden-Sydney C	8	1	—	—			
Hampton U	6	0	0	—			
Hartford, U of	1	1	0	—			
Hartwick C	1	6	—	—			
Harvard U	20	3	26	40			
Harvey Mudd C	10	0	—	—			
Haverford C	10	1	—	—			
Hawaii, U of	8	10	4	9			
Hendrix C	4	0	—	—			
Hiram C	5	3	—	—			
Hobart & William Smith C	2	3	—	—			
Hofstra U	3	1	—	—			
Hollins C	0	3	—	—			
Holy Cross, C of the	18	4	—	—			
Hope C	21	13	—	—			
Houston, U of	8	1	5	14	37	14	6
Howard U	2	25	1	9	14	2	—
Humboldt State U	3	3	—	—			
Idaho State U	4	3	—	—			
Idaho, U of	4	6	8	5	24	12	2
Illinois Benedictine C	6	1	—	—			
Illinois Institute of Tech	3	0	6	1	29	10	3
Illinois State U	48	4	12	—			
Illinois Wesleyan U	4	0	—	—			
Illinois, U of							
Chicago	13	34	7	10	23	14	5
Urbana-Champaign	34	69	16	26	68	10	8
Indiana State U	7	1	1	—			
Indiana U-Purdue U							
Fort Wayne	5	4	0	—			
Indianapolis	6	14	9	1			
Indiana U							
Bloomington	32	117	10	29			
Northwest	2	1	—	—			
South Bend	3	0	—	—			
Southeast	2	9	—	—			
Indiana U of Pennsylvania	5	2	4	—			
Interamerican U of Puerto Rico	4	8	—	—			
Iowa State U	9	5	5	30	33	3	9
Iowa, U of	16	2	12	23	15	1	1
Ithaca C	8	5	—	—			
Jackson State U	5	9	2	—			
James Madison U	6	18	—	—			
John Carroll U	3	15	3	—			
Johns Hopkins U	21	0	21	16	13	4	5
Juniata C	4	7	—	—			
Kalamazoo C	4	10	—	—			
Kansas State U	5	8	4	8	23	5	0
Kansas, U of	2	18	4	7	26	4	1
Kean C of New Jersey	3	5	—	—			
Kennesaw State C	1	4	—	—			
Kent State U	15	13	1	7			
Kentucky, U of	7	9	3	7	22	4	2
Kenyon C	5	6	—	—			
King's C	2	0	—	—			
Knox C	1	17	—	—			
La Salle U	7	2	—	—			
Lafayette C	3	5	—	—	18	—	—
Lake Forest C	2	1	—	—			
Lamar U	4	2	6	—	(a)		
Lawrence Technological U	9	0	—	—			
Lawrence U	2	8	—	—			
LeMoyne C	4	0	—	—			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Lebanon Valley C	3	2	—	—			
Lehigh U	2	2	15	11	29	8	5
Lewis & Clark C	0	5	—	—			
Lincoln U	1	15	—	—			
Long Island U							
Brooklyn Campus	0	0	5	—			
C. W. Post Campus	1	0	—	—			
Loras C	1	3	—	—			
Louisiana State U							
Baton Rouge	6	5	5	7	42	15	1
Shreveport	0	5	—	—			
Louisiana Tech U	1	4	4	—	20	5	3
Louisville, U of	15	9	1	5	(a)		
Loyola C in Maryland	1	0	—	—			
Loyola Marymount U	1	0	—	—			
Loyola U							
Chicago	8	3	5	3			
New Orleans	4	2	—	—			
Luther C	0	6	—	—			
Lycoming C	2	0	—	—			
Macalester C	4	6	—	—			
Maine, U of	4	1	2	6	38	4	0
Manhattan C[c]	4	5	—	—	14	9	—
Mankato State U	6	10	1	—			
Marietta C	1	1	—	—			
Marist C	4	0	—	—			
Marquette U	8	0	6	5			
Marshall U	3	21	3	—			
Maryland, U of							
Baltimore County	9	35	6	5	14	6	3
College Park	3	37	5	11	(a)		
Massachusetts Institute of Tech	33	0	4	51	(a)		
Massachusetts, U of							
Amherst	17	3	6	12	20	6	7
Boston	2	21	1	—			
Dartmouth	0	10	3	—			
Lowell	2	8	6	19	12	7	—
McNeese State U	0	0	4	—			
Memphis, U of	1	9	4	2			
Mercer U	1	4	—	—			
Merrimack C	8	1	—	—			
Metropolitan State C	3	17	—	—			
Miami U	11	27	3	7			
Miami, U of	6	11	2	5			
Michigan State U	26	10	9	25	(a)		
Michigan Technological U	11	0	6	1	(a)		
Michigan, U of							
Ann Arbor	56	0	10	20	86	17	7
Dearborn	10	11	—	—			
Flint	2	12	—	—			
Middle Tennessee State U	3	24	2	0			
Middlebury C	0	11	—	—			
Midwestern State U	5	4	—	—			
Millersville U	3	9	—	—			
Millikin U	7	4	—	—			
Millsaps C	5	10	—	—			
Minnesota, U of							
Duluth	8	17	3	—	16	—	—
Minneapolis	32	0	7	39	101	7	30
Mississippi C	4	6	—	—			
Mississippi State U	2	4	2	3	(a)		
Mississippi, U of	7	6	6	4	11	7	0
Missouri, U of							
Columbia	9	4	6	9	36	10	1
Kansas City	3	16	6	1			
Rolla	13	0	8	6	(a)		
St. Louis	8	12	12	4			
Missouri Western State C	4	4	—	—			
Monmouth C	3	0	—	—			
Montana C of Mineral Science & Tech	3	3	1	—			
Montana State U	1	5	3	11	(a)		
Montana, U of	2	5	1	2			
Montclair State C	2	6	4	—			
Moorhead State U	2	3	—	—			
Moravian C	0	0	—	—			
Morehouse C	5	1	—	—			
Morgan State U	8	6	—	—			
Mount Holyoke C	7	0	0	—			
Mount Saint Vincent, C of[c]	0	1	—	—			
Muhlenberg C	5	2	—	—			
Murray State U	3	11	4	—			
Muskingum C	0	3	—	—			
Nazareth C	1	0	—	—			
Nebraska Wesleyan U	2	3	—	—			
Nebraska, U of							
Kearney	1	11	—	—			
Lincoln	2	8	10	11	15	9	1
Omaha	2	1	—	—			
Nevada, U of							
Las Vegas	3	5	2	—			
Reno	2	4	3	3	(a)		
New Hampshire, U of	7	2	3	7	15	4	3
New Jersey Institute of Tech[b]					(a)		
New Mexico Highlands U	0	4	1	—			
New Mexico Institute of Mining & Tech	5	0	3	2			
New Mexico State U	0	18	3	3	(a)		
New Mexico, U of	12	4	4	9	9	11	3
New Orleans, U of	2	7	5	9			
New York U	1	26	11	12			
Niagara U	1	1	—	—			
North Alabama, U of	8	9	—	—			
North Carolina A&T State U	4	0	4	—	18	—	—
North Carolina Central U	0	6	1	—			
North Carolina State U	25	85	5	7	(a)		
North Carolina, U of							
Asheville	2	3	—	—			
Chapel Hill[d]	32	47	11	40			
Charlotte	6	5	2	—			
Greensboro	4	6	1	—			
Wilmington	4	17	0	—			
North Dakota State U	3	15	5	9			
North Dakota, U of	2	5	1	1	20	4	—
North Texas, U of	7	4	10	7			
Northeast Louisiana U	5	0	3	—			
Northeast Missouri State U	17	0	—	—			
Northeastern Illinois U	0	8	4	—			
Northeastern U	7	0	6	3	(a)		
Northern Arizona U	10	17	11	—			
Northern Colorado, U of	3	7	1	2			
Northern Illinois U	8	5	10	5			
Northern Iowa, U of	11	14	0	—			
Northern Kentucky U	0	8	—	—			
Northern Michigan U	1	14	0	—			
Northwest Missouri State U	3	4	—	—			
Northwestern State U of Louisiana	0	0	—	—			
Northwestern U	15	17	40	36	43	8	19
Notre Dame, U of	7	13	4	9	31	12	5
Oakland U	3	0	2	1			
Oberlin C	10	19	—	—			
Occidental C	6	9	—	—			
Ohio Northern U	10	4	—	—			
Ohio State U	27	8	21	33	(a)		
Ohio U	7	15	3	4	26	5	2

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Ohio Wesleyan U	2	11	—	—			
Oklahoma State U	4	3	1	7	21	10	2
Oklahoma, U of	11	19	8	10	26	9	2
Old Dominion U	5	11	6	—			
Oregon State U	16	2	8	10	(a)		
Oregon, U of	7	29	12	12			
Pace U							
New York	1	2	—	—			
Pleasantville	2	4	—	—			
Pacific Lutheran U	2	10	—	—			
Pacific, U of the	0	5	2	2			
Pennsylvania State U	17	9	8	28	113	5	8
Pennsylvania, U of	0	23	3	17	20	7	9
Philadelphia C of Pharmacy & Science	2	3	0	2			
Philadelphia C of Textiles & Science	2	1	—	—			
Pittsburg State U	3	7	4	—			
Pittsburgh, U of	12	50	12	23	(a)		
Polytechnic U	1	0	11	7	(a)		
Pomona C	4	8	—	—			
Portland State U	0	9	3	4			
Portland, U of	2	1	—	—			
Princeton U	16	8	0	17	(a)		
Providence C	1	3	—	—			
Puerto Rico, U of							
Mayaguez	8	23	2	—	(a)		
Rio Piedras	10	12	8	4			
Puget Sound, U of	6	4	—	—			
Purdue U	18	25	11	43	117	10	18
Purdue U Calumet	5	2	—	—			
Ramapo C of New Jersey	6	0	—	—			
Randolph-Macon C	0	6	—	—			
Randolph-Macon Women's C	1	1	—	—			
Redlands, U of	0	3	—	—			
Reed C	7	8	—	—			
Rensselaer Polytechnic Institute	6	0	12	8	54	15	12
Rhode Island C	1	4	—	—			
Rhode Island, U of	5	2	2	2	8	2	3
Rhodes C	3	7	—	—			
Rice U	7	13	9	12	12	7	6
Richmond, U of	0	15	—	—			
Rider C	6	0	—	—			
Ripon C	3	2	—	—			
Roanoke C	3	2	—	—			
Rochester Institute of Tech	19	7	5	—			
Rochester, U of	7	3	24	14	22	5	9
Rockhurst C	1	4	—	—			
Rollins C	1	0	—	—			
Roosevelt U	9	0	3	—			
Rose-Hulman Institute of Tech	6	0	—	—	26	0	—
Rowan C of New Jersey	7	4	—	—			
Russell Sage C	2	0	—	—			
Rutgers U							
Camden C	3	4	—	—			
New Brunswick	12	27	12	15	34	8	3
Newark C	5	3	5	9			
Saginaw Valley State U	5	16	—	—			
St. Anselm C	3	0	—	—			
St. Benedict, C of/ St. John's U	4	11	—	—			
St. Catherine, C of	2	3	—	—			
St. Cloud State U	2	7	—	—			
St. John Fisher C	5	6	—	—			
St. John's U	2	1	4	—			
St. Joseph C	0	1	5	—			
St. Joseph's U	6	6	7	—			
St. Lawrence U	2	7	—	—			
St. Louis U	7	18	3	—			
St. Mary's C	0	0	—	—			
St. Michael's C	3	2	—	—			
St. Olaf C	2	46	—	—			
St. Peter's C	1	1	—	—			
St. Thomas, U of	4	12	—	—			
St. Vincent C[a]	5	0	—	—			
Salem State C	12	0	—	—			
Salisbury State U	3	2	—	—			
Sam Houston State U	3	15	6	—			
San Diego State U	17	5	8	3			
San Diego, U of	0	7	—	—			
San Francisco State U	8	26	8	—			
San Francisco, U of	11	0	1	—			
San Jose State U	10	11	3	—	(a)		
Sangamon State U	2	2	—	—			
Santa Clara U	2	4	—	—			
Scranton, U of	4	10	12	—			
Seattle U	0	3	—	—			
Seton Hall U	4	4	9	2			
Seton Hill C[a]	4	0	—	—			
Shippensburg U	5	3	0	—			
Siena C	3	0	—	—			
Simmons C	0	5	—	—			
Skidmore C	0	10	—	—			
Smith C	5	4	—	—			
Sonoma State U	0	10	—	—			
South Alabama, U of[b]					17	5	—
South Carolina, U of	5	21	5	23	19	9	0
South Dakota School of Mines & Tech	3	0	2	—	24	4	—
South Dakota State U	0	27	5	2			
South Dakota, U of	4	5	4	—			
South Florida, U of	17	55	7	4	(a)		
Southeast Missouri State U	0	9	—	—			
Southeastern Louisiana U	3	0	—	—			
Southern California, U of	15	6	1	11	12	17	2
Southern Colorado, U of	1	3	1	—			
Southern Illinois U							
Carbondale	8	5	9	9			
Edwardsville	14	13	9	—			
Southern Methodist U	6	9	1	—			
Southern Mississippi, U of	2	19	0	4			
Southern Oregon State C	3	2	—	—			
Southern U and A&M C	10	1	5	—			
Southwest Missouri State U	5	19	—	—			
Southwest State U	2	5	—	—			
Southwest Texas State U	11	0	2	—			
Southwestern Louisiana, U of	1	3	2	—	8	6	—
Southwestern Oklahoma State U	1	8	—	—			
Stanford U	7	8	3	30	13	10	8
State U of New York							
Albany	15	0	3	4			
Binghamton	10	10	3	4			
Buffalo	9	5	4	26	32	4	2
Stony Brook	17	23	9	19			
C at Brockport	3	2	—	—			
C at Buffalo	1	11	1	—			
C at Cortland	3	4	—	—			
C at Fredonia	10	2	2	—			
C at Geneseo	2	4	—	—			
C at New Paltz	4	5	5	—			
C at Oneonta	1	13	—	—			
C at Oswego	15	6	4	—			
C at Plattsburgh	5	6	1	—			
C at Potsdam	3	5	—	—			
C at Purchase	3	2	—	—			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Stephen F. Austin State U	1	5	1	—			
Stetson U	0	1	—	—			
Stevens Institute of Tech	16	0	14	2	14	18	2
Stockton C of New Jersey	6	4	—	—			
Suffolk U	0	7	—	—			
Susquehanna U	1	2	—	—			
Swarthmore C	5	10	—	—			
Syracuse U	8	1	4	6	11	3	3
Temple U	2	19	6	7			
Tennessee Technological U	3	14	5	—	35	5	1
Tennessee, U of							
Chattanooga	20	27	—	—			
Knoxville	1	11	7	10	34	6	7
Martin	2	5	—	—			
Texas A&M U							
College Station	16	10	4	44	75	17	11
Kingsville	7	0	1	—	24	10	—
Texas Christian U	3	11	0	4			
Texas Southern U	5	3	7	—			
Texas Tech U	17	30	4	12	(a)		
Texas, U of							
Arlington	3	10	4	6			
Austin	75	0	5	32	(a)		
Dallas	7	0	5	1			
El Paso	4	0	6	—			
Texas Woman's U	0	6	4	—			
Thiel C	0	3	—	—			
Toledo, U of	6	7	4	3	19	4	1
Towson State U	3	10	—	—			
Trenton State C	22	0	—	—			
Tri-State U[b]					8	—	—
Trinity C	6	3	0	—			
Trinity U	19	0	—	—			
Tufts U	0	14	5	4	(a)		
Tulane U	0	17	2	5	(a)		
Tulsa, U of	4	0	—	—	(a)		
Tuskegee U	0	6	0	—	24	—	—
Union C	3	3	—	—			
U.S. Air Force Academy	23	1	—	—			
U.S. Naval Academy	22	0	—	—			
Ursinus C	5	1	—	—			
Utah State U	9	0	5	5			
Utah, U of	3	27	6	9	23	1	8
Valparaiso U	5	20	—	—			
Vanderbilt U	2	28	13	8	24	5	3
Vassar C	1	0	0	—			
Vermont, U of	9	0	0	6			
Villanova U	6	0	9	3	37	10	—
Virginia Commonwealth U	4	20	0	3			
Virginia Military Institute	6	0	—	—			
Virginia Polytechnic Institute & State U	24	30	6	20	50	0	2
Virginia, U of	(a)				31	23	3
Wabash C	4	5	—	—			
Wagner C	4	0	—	—			
Wake Forest U	6	11	0	4			
Washburn U of Topeka	0	6	—	—			
Washington C	1	0	—	—			
Washington State U	12	4	7	2	22	7	0
Washington U	2	24	7	10	39	9	6
Washington & Jefferson C	2	10	—	—			
Washington & Lee U	0	17	—	—			
Washington, U of	26	43	15	23	54	2	10
Wayne State U	10	29	3	23	36	19	4
Waynesburg C	2	1	—	—			
Weber State U	5	5	—	—			
Wellesley C	11	18	—	—			
Wesleyan U	6	3	0	6			
West Chester U	4	17	5	—			
West Florida, U of	5	4	—	—			
West Virginia Institute of Tech[b]					13	—	—
West Virginia State C	1	5	—	—			
West Virginia U	7	32	3	3	27	4	3
Western Illinois U	0	3	7	—			
Western Kentucky U	5	37	5	—			
Western Maryland C	0	6	—	—			
Western Michigan U	4	9	3	1			
Western Washington U	12	10	2	—			
Westminster C	0	5	—	—			
Wheaton C							
Illinois	5	7	—	—			
Massachusetts	2	6	—	—			
Whitman C	0	10	—	—			
Whittier C	0	8	—	—			
Wichita State U	1	10	1	3			
Widener U	1	3	—	—	(a)		
Wilkes U	1	1	—	—			
Willamette U	0	11	—	—			
William Paterson C of New Jersey	0	4	—	—			
William & Mary, C of	39	11	8	—			
Williams C	3	30	—	—			
Winona State U	1	4	—	—			
Wisconsin, U of							
Eau Claire	6	20	—	—			
Green Bay	0	9	—	—			
La Crosse	5	11	—	—			
Madison	33	0	8	37	(a)		
Milwaukee	2	14	7	3			
Oshkosh	6	6	—	—			
Parkside	10	0	—	—			
Platteville	0	2	—	—			
River Falls	6	5	—	—			
Stevens Point	4	10	—	—			
Superior	4	1	—	—			
Wittenberg U	3	5	—	—			
Wooster, C of	2	14	—	—			
Worcester Polytechnic Institute	5	3	0	2	31	1	4
Wright State U	15	2	14	—			
Wyoming, U of	4	2	0	2	16	4	0
Xavier U	3	5	—	—			
Xavier U of Louisiana	1	33	—	—			
Yale U	0	17	17	20	6	10	1
Youngstown State U	5	30	2	—	7	—	—
TOTALS	3,605	5,195	1,683	2,140	3,164	705	435

Note: For brevity, "B.S." and "M.S." are used to denote all bachelor's and master's degrees, respectively, in each column. a. Data not submitted. b. Listed on basis of accreditation by AIChE-ABET. c. The chemistry programs at Mount Saint Vincent and Manhattan College are integrated into a combined department with instruction in chemistry located at Manhattan College. d. UNC, Chapel Hill, Curriculum in Applied Sciences degrees are combined with the chemistry department degrees. e. Saint Vincent College and Seton Hill College are integrated into a combined department.

UCLA, Berkeley top producers of chemists

The University of California, Los Angeles; Cornell University; and the University of California, Berkeley, were, in that order, the largest producers of new bachelor's, master's, and Ph.D. chemists in the 1992–93 academic year.

The total number of new bachelor's degree chemists was up 4.3% to 8,800. This trend is now three years old, but numbers are still off from the high reached in 1984–85, when there were 9,679 such graduates. The number of Ph.D.s dropped for the second year in a row, down nearly 3%.

These are some of the notable points in the latest report of ACS's Committee on Professional Training (CPT). CPT gathers graduation data annually from chemistry departments with undergraduate programs it has approved. These departments account for about 90% of all new bachelor's degree chemists and for essentially all advanced chemistry degrees.

In 1992–93, UCLA moved up from third position to edge out the 1991–92 leader, Indiana University, Bloomington, for the top spot as largest producer of B.S. chemists. North Carolina State University took the third slot in 1992–93, while the University of Illinois, Urbana-Champaign, dropped from second to fourth.

Cornell regained the top spot as the largest producer of master's graduates. It was followed by Northwestern University, which rose from sixth place in 1991–92. City University of New York, City College, rose from 24th place in 1991–92 to take third place. Johns Hopkins University, the top master's producing school in 1991–92, dropped to sixth.

Last year was the ninth consecutive year that UC Berkeley headed the list of Ph.D. producers. Massachusetts Institute of Technology moved up three places to the second spot, followed by Texas A&M University, up five places to the third spot. Illinois, the 1991–92 second-place school, dropped to 20th place.

The University of Texas, Austin, retained its status as the largest producer of certified bachelor's graduates. UC San Diego and the University of Michigan, Ann Arbor, came in second and third, respectively, in the current report. Those who complete an approved curriculum are immediately eligible for ACS membership.

Linda Ross

These schools had the most chemistry graduates, 1992-93

Total bachelor graduates

1.	U of California, Los Angeles	152
2.	Indiana U, Bloomington	149
3.	North Carolina State U	110
4.	U of Illinois, Urbana-Champaign	103
5.	U of North Carolina, Chapel Hill	79
6.	U of Texas, Austin	75
7.	U of South Florida	72
8.	U of California, San Diego	70
9.	U of Washington	69
10.	U of California, Irvine	64
11.	U of California, Berkeley	62
11.	U of Pittsburgh	62
13.	California Poly State U	61
14.	U of California, Davis	57
15.	U of Michigan, Ann Arbor	56
16.	Virginia Poly Inst & State U	54
17.	U of Colorado, Boulder	52
17.	Illinois State U	52
19.	California State U, Long Beach	50
19.	C of William & Mary	50
21.	St. Olaf C	48
22.	U of Illinois, Chicago	47
22.	U of Tennessee, Chattanooga	47
22.	Texas Tech U	47
25.	U of Maryland, Baltimore County	44

Certified bachelor graduates

1.	U of Texas, Austin	75
2.	U of California, San Diego	69
3.	U of Michigan, Ann Arbor	56
4.	Illinois State U	48
5.	U of California, Davis	41
6.	C of William & Mary	39
7.	U of Illinois, Urbana-Champaign	34
8.	Massachusetts Inst of Tech	33
8.	U of Wisconsin, Madison	33
10.	Indiana U, Bloomington	32
10.	U of Minnesota, Minneapolis	32
10.	U of North Carolina, Chapel Hill	32
13.	Georgia Tech U	29
14.	Ohio State U	27
15.	U of Cincinnati	26
15.	Michigan State U	26
15.	U of Washington	26
18.	U of Delaware	25
18.	Furman U	25
18.	North Carolina State U	25
21.	Virginia Poly Inst & State U	24
22.	U of California, Berkeley	23
22.	U.S. Air Force Academy	23
24.	Creighton U	22
24.	Trenton State C	22
24.	U.S. Naval Academy	22

Master graduates

1.	Cornell U	46
2.	Northwestern U	40
3.	City U of New York, City C	30
4.	Harvard U	26
5.	U of Rochester	24
6.	Johns Hopkins U	21
6.	Ohio State U	21
8.	U of California, San Diego	19
9.	U of Detroit, Mercy	17
9.	Yale U	17
11.	U of Cincinnati	16
11.	U of Illinois, Urbana-Champaign	16
13.	Lehigh U	15
13.	U of Washington	15
15.	Stevens Inst of Tech	14
15.	Wright State U	14
17.	U of California, Irvine	13
17.	Georgia Southern U	13
17.	Vanderbilt U	13
20.	U of California, Los Angeles	12
20.	DePaul U	12
20.	Illinois State U	12
20.	U of Iowa	12
20.	U of Missouri, St. Louis	12
20.	U of Oregon	12
20.	U of Pittsburgh	12
20.	Rensselaer Poly Inst	12
20.	Rutgers U, New Brunswick	12
20.	U of Scranton	12

Doctoral graduates

1.	U of California, Berkeley	54
2.	Massachusetts Inst of Tech	51
3.	Texas A&M U	44
4.	Purdue U	43
5.	U of California, Los Angeles	41
6.	Harvard U	40
6.	U of North Carolina, Chapel Hill	40
8.	U of Minnesota, Minneapolis	39
9.	U of Wisconsin, Madison	37
10.	Northwestern U	36
11.	U of California, San Diego	35
12.	Ohio State U	33
13.	U of Texas, Austin	32
14.	California Inst of Tech	30
14.	Iowa State U	30
14.	Stanford U	30
17.	Indiana U, Bloomington	29
18.	City U of New York, Grad Center	28
18.	Pennsylvania State U	28
20.	Cornell U	26
20.	U of Florida	26
20.	U of Illinois, Urbana-Champaign	26
20.	Michigan State U	26
24.	U of Washington	25
25.	U of Cincinnati	24